Does Public Capital Spur Private Investment in Developing Economies?

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Abstract

What drives private investment in a country is a question of paramount importance to both researchers and policy makers. Additions to a country's private capital stock help drive both faster growth and faster wealth creation, which often creates many positive spillover effects for a country's populace. In a study of twenty-two developing countries over a total of 660 country-year observations utilizing vector error correction models, this report found preliminary evidence that public capital stock growth positively caused growth in future values of the private capital stock in a country. Additionally, this study found that changes in the level of the population and changes in the strength of political institutions also caused changes in the level of the stock of private capital in a developing country. Tentative causal evidence also existed for changes in the domestic credit to the private sector as a share of GDP, financial openness, and the size of the economy causing changes in the stock of private capital in a country. Policy makers in developing countries should focus future efforts on improving the quality of their institutions and providing high quality infrastructure, both traditional and social, if they want to help increase their country's private capital formation and, consequently, growth.

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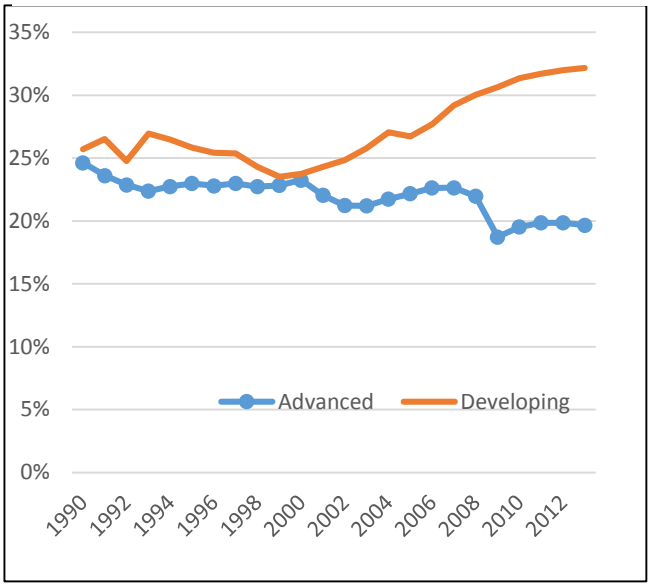
CHAPTER 1: INTRODUCTION

While it is commonly understood that investment is one of the major drivers of growth in both developing and advanced economies around the world, the question of what drives investment is much less well understood. This is especially the case for developing economies, where it is an arguably even more salient issue than for advanced economies. As many developing and advanced economies have seen investment decline in the aftermath of the Global Financial Crisis due to both endogenous and exogenous developments, this question is increasingly important in order to avoid the onset of hysteresis and the damaging idling of workers who could otherwise be employed productively. If governments are able to tailor their policies and priorities to best meet the needs of private sector actors, this would aid in both catching up from any lost growth experienced during the past half-decade-plus and maximize growth going forward.

Even though total investment was basically flat globally during the previous four years (2010-13) compared to the four years before that (2006-09), there has been a wide divergence between investment trends in advanced and developing economies since 2008. In advanced economies investment as a share of GDP reached a cyclical peak in 2007. Since that time, when investment represented 22.6% of advanced economies' GDP,

investment declined to 19.7% in 2013. By contrast, investment went from 29.5% of emerging economies' GDP in 2007 to 32.8% in 2013. Among the regions, growth was swiftest in developing Asia over that time period, with investment going from 37.4% of GDP in 2007 to 43.5% in 2013. By contrast, Euro Area investment cratered. It went from 22.7% of GDP to 17.9%. Among the other developing regions, Sub-Saharan Africa's investment share of GDP increased by nearly 1%-point, but the investment share of GDP declined in other developing regions. Investment in Central and Eastern Europe experienced notable declines, going from 24.7% of GDP in 2007 to 20.5% in 2013. While the investment share of GDP in North American and advanced Asian economies declined on average, the declines were much less than the one seen in the Eurozone. Although developing Asia and, to a lesser extent, Sub-Saharan Africa, have set themselves up for solid growth in output going forward, most other regions in the world have taken a step back. Even Asia's growth outlook, fueled in part by a large increase in debt in China, is filled with potential headwinds despite the uptick in investment given the legitimate questions about the quality of the investments that occurred in recent years.

Figure 1. Total investment as a Share of GDP by Development Level: 1990-2013



Source: IMF

This recent decline in investment followed a decade of tremendous investment in infrastructure facilities that coincided with a strong period of growth in private investment in developing economies following a relatively weak period of growth during the 1990s. Global electricity generation capacity increased by 86% between 1990 and 2010, with the average annual rate of growth accelerating by 65% after 2000 compared to before then. The global paved road network increased by 43% over the two-plus decades, with annual average growth jumping from 1.0% during the first half of the study to 2.6% during the second half. Port traffic increased by 560% over this time period, with growth remaining a robust 8.2% during the second half of the study's sample period. Although the global rail network increased by just 8% during the two-plus decades, average annual growth was 1.4% during the second half of the study compared to an annual contraction of 0.6% during the first half. The number of households with access to improved sanitation facilities jumped by 84% over that same period of time, and the number of households with improved water facilities rose by 70%. Growth was relatively evenly distributed over the two halves for both types of connections. The growth rate of many telecommunications-related assets was quite robust during the 2000s with the exception of fixed telephone lines, and there were over 5 billion mobile telephone subscriptions around the world at the beginning of this decade. During this period of expansion of traditional infrastructure projects, private investment in developing economies increased dramatically. With some assumptions and extrapolation, the annual growth rate of private gross fixed capital formation—also known as investment—jumped from 5.9% between 1990 and 2000 to 14.5% between 2000 and 2010.

This study aims to contribute to the literature on the subject by investigating what determines the level of private investment in developing economies through a vector autoregression-based analysis of nearly twenty-five such economies over the last four decades. Specifically, this study's goal is to determine if there is a causal relationship between public and private investment. A great debate has emerged within academic circles concerning whether infrastructure investment, traditionally the province of the state for many developing economies, crowds out or complements private investment. The findings from this study hopefully shed preliminary insight into optimal conditions for the building of a country's private capital stock and how policy actions can be geared toward creating a growth-maximizing environment in the future. The specific policy recommendations vary dramatically depending on the answers to the questions posed by this report.

This report differs from many existing studies on this subject in five important respects. First, most previous studies on this subject analyze the question of whether infrastructure investment—or a commonly-used proxy such as gross public fixed capital formation—affects a country's output. Second, many prior studies have explored the issue of the effect of public investment spending on private investment or an economy's overall level of output by looking at the rates of growth of these variables as opposed to changes in the levels of the stock forms of these variables. Thirdly, a decided majority of these studies have utilized panel data analysis econometric techniques in order to answer the key questions. Fourth, of the studies that have utilized time-series analysis econometric techniques, the studies generally confined themselves to exploring the effect of public investment spending on private investment spending or overall output of just a single

country. Fifth, most time-series-based analyses look at the relationship between public and private capital on a contemporaneous or near-contemporaneous relationship. This study's novelty lies in the fact that it explores the link between public investment and private investment, it utilizes stocks of private and public capital, it uses time-series econometric techniques, it evaluates the effect of public capital stock growth on private capital stock growth for nearly two dozen countries, and it looks at the lagged effects between public capital and private capital formation.

This study analyzes these issues in the following order. Chapter two examines previous academic and non-academic literature on the importance of public gross fixed capital formation in affecting private investment growth rates and levels over time. Chapter three evaluates the evolution of many traditional infrastructure assets in the energy, transportation, water and sanitation, and telecommunications sectors, which in general remain the province of the public sector for the sorts of middle and low income countries that this study analyzes. Chapter four details the methodology used in answering the overarching question of this thesis. Chapter five presents the results of causality tests for the over twenty countries that this study looks at in terms of whether changes in the level of the stock of the universe of potential explanatory variables leads to changes in the level of the stock of private capital. The findings from this chapter will be incorporated in chapter six, which investigates whether the additional public capital formation crowds-in or crowds-out private capital formation once other causal explanatory variables are controlled for in the models. This study concludes in chapter seven with analysis of these findings and the policy implications that are derived from them.

CHAPTER 2: LITERATURE REVIEW

Infrastructure investment's role in driving growth has experienced a renaissance of interest within academic circles during the past twenty-five years. In recent decades, the primary line of inquiry was determining if infrastructure investment had a positive effect on output growth in different types of economies. David Aschauer revitalized interest in this subject in the late 1980s with his seminal paper on the subject of the relationship between infrastructure investment and economic growth in 1989, which estimated the elasticity of total factor productivity to infrastructure investment was 0.34 in the United States.

There are a variety of underlying theories that motivate researchers into analyzing whether infrastructure investment has a positive or negative effect on an economy's output growth rate. A number of studies, most notably Calderon, Moral-Benito, and Serven (2011), Canning and Pedroni (2004), and Shioji (2001), attempt to include infrastructure investment and/or public capital as an explanatory variable in an aggregate production function with overall output as the explained variable and various specifications of physical and human capital as the other explanatory variables. Romp and de Haan (2005) review some of the other major theoretical frameworks employed by researchers when analyzing the effect that infrastructure investment has on output growth. There have also been many researchers who have utilized the cost-function approach—including Demetriades and Mamuneas (2000)—when analyzing the effect of infrastructure investment on output growth. A good portion of this interest is due to the fact that the production-function approach violates standard marginal productivity theory, whereas cost-function approaches

sidestep this violation by assuming that public capital/infrastructure is a free input externally provided by the government. In these models, the question is whether public capital reduces costs for firms that allows them to increase overall output in an economy during their profit-maximization process. Additionally, a number of researchers, including Kamps (2004), have attempted to investigate this subject by using vector autoregression models. The advantage of these models is the lack of a priori assumptions concerning causality and the fact that explained and explanatory variables can be jointly determined.

While Aschauer may have renewed interest in the subject matter, he was certainly not the first researcher to investigate the relationship between government spending/infrastructure and GDP growth. Barro (1980) found that although defense purchases had a large positive effect on output growth in the United States, the effect of non-defense purchases on output growth could not be determined. By contrast, Eberts (1986) found that the public capital stock had a statistically significant positive influence on the growth of manufacturing output in different metropolitan areas around the country, although the economic effects of public capital were smaller than those for private capital and labor.

As the relationship between infrastructure investment and growth was investigated by other researchers after Aschauer with more advanced econometric techniques, larger longitudinal samples, and additional countries, a general consensus eventually emerged that investment in infrastructure is associated with materially improved growth rates, if smaller than the impact estimated by Aschauer. In general, the elasticity of output growth with respect to infrastructure investment ranges between 0.08 and 0.22 in studies that

investigate more than one country at a time, with every additional unit of infrastructure investment boosting output by an additional 0.08 to 0.22 units. These results indicate that a 10% increase in infrastructure investment is associated with a 0.8% to 2.2% marginal increase in GDP. Romp and Haan (2005) reviewed over fifty of the academic studies investigating a link between infrastructure investment and either growth or welfare since Aschauer's initial study. Of the fifty-three studies that directly attempt to answer the question, forty-four of them found that infrastructure investment had a positive effect on growth or welfare. Of the remaining studies, five could not find conclusive evidence of any effect while four found that infrastructure investment had a negative effect on growth. Calderon, Moral-Benito, and Serven (2011) found that the long-run elasticity of output with respect to infrastructure stock ranged between 0.07 and 0.10. These results indicate that a 10% increase in infrastructure investment is associated with a 0.7%-1.0% marginal increase in GDP.

Sanchez-Robles (1998) analyzed any possible effects that infrastructure investment has on economic output through the use of physical infrastructure assets—such as kilometers of road network, electric capacity, rail network, etc.—as a proxy for infrastructure endowment. The advantage of this particular form of measuring infrastructure's effect on output growth is that it helps delink inflated construction costs resulting from corruption from the investment necessary to simply build the physical asset itself. This method allows for a purer measure of the effect infrastructure investment has on GDP growth. This study found that infrastructure investment had a positive impact on developing country's GDP growth rates.

While most studies on the effects of infrastructure investment on output growth lump new investment in with maintenance spending on existing infrastructure assets, Rioja (2003) separated the two components of infrastructure investment and produced some novel findings. Rioja's analysis found that developing economies can maximize infrastructure investment's positive effects on output growth when 2% of GDP is devoted to such spending. His study found that most Latin American countries fell below this optimal allocation during the course of his study.

Esfahani and Ramirez (2003) further advanced research into the variety of ways that infrastructure investment can influence growth rates by emphasizing the effect that institutions played on GDP growth and the effectiveness of government policy. In particular, the researchers found that once institutions and infrastructure investment are controlled for, and accounting for the simultaneity between infrastructure investment and GDP, infrastructure investment had a "substantial" impact on GDP growth rates. The two researchers also found that credible and effective institutions play an important role in determining the effectiveness of infrastructure investment.

While there may be specific niches that have not yet been fully examined within the relationship between infrastructure investment and output growth, most of the pertinent questions appear to have been investigated based on the accumulated research to date on the subject.

A decidedly smaller minority of studies have examined the role that infrastructure investment plays in driving private investment. Many to most of these studies focus on the question of whether public investment "crowds out" private investment. These studies generally measure public and private investment in terms of flows—i.e. growth rate—as opposed to stocks—i.e. the level of public capital. Additionally, until recently, the questions were primarily answered with panel data techniques, such as fixed effects, random effects, pooled OLS, and two-stage least squares instrumental variable regressions, which will be discussed in detail later on in this study. The key question in this debate is whether the positive effect on the profit function of increasingly productive public capital outweighs the negative effect of crowding-out of private investment with each additional unit of public investment. Most of these studies focus on contemporaneous relationships between public and private investment. The studies to date have failed to yield a definitive consensus on which effect dominates.

The underlying theoretical frameworks that motivate analyzing the relationship between public capital and private capital are similar to those that motivate analyzing the relationship between public capital and overall output growth. Hatano (2010) is one of many researchers who utilize a production function approach to undergird theories of how public capital could increase or decrease the accumulation and/or effectiveness of private capital. As alluded to previously, for aggregate production function-based studies the models in these studies attempt to determine whether the positive effect on the profit function of increasingly productive public capital outweighs the negative effect of crowding-out of private investment with each additional unit of public investment. In

certain cases, the authors will still utilize VAR/VECM models, but the underlying theories behind the creation of the models is still motivated by an aggregate production function framework. Additionally, cost/profit function models are employed by many researchers, including Bosca, Escriba, and Murgui (2000). These types of studies attempt to determine whether public capital makes new incremental private investment more or less profitable. If the answer is "more profitable", private firms will invest more and increase the private capital stock. Finally, a number of researchers, including Mittnik and Neumann (2001), employ vector autoregression and/or vector error correction models when exploring this subject.

Of the studies that examine the question of the relationship between public and private infrastructure investment, there are a number of studies that examine this question with panel data analysis techniques. Erden and Holcombe (2005) found evidence that a 10% increase in public investment is associated with a 2% increase in private investment in developing economies, but that there is evidence of crowding-out in advanced economies. Oshikoya (1994) examined the determinants of private investment of various middle income and low income African countries between 1970 and 1988, and his pooled OLS results indicated that there was a complementary relationship between public and private investment among both groups of countries, although the relationship was more economically significant among middle income African countries. His examination of the relationship within individual countries pointed to a need to ensure that types of public investment pursued were productive, but caution is necessary in drawing too sweeping of conclusions from such a small relative sample size. Greene and Villanueva (1991) pooled

cross section analysis of the determinants of private sector investment among developing economies between 1975 and 1987 also found a complementary relationship between public and private investment.

Aschauer (1989) discovered evidence of a crowding-in relationship between public and private investment in the United States. Lora (2007) discovered evidence of crowding-in between private and public investment in many Latin American countries between the late 1980s and early 2000s. Mitsui, Takezawa, and Kawachi (1995) found evidence of a crowding-in relationship as well.

By contrast, Cavallo and Daude (2008) found through their analysis of 116 developing countries between 1980 and 2006 that a crowding-out effect was present across most regions and time. Good governance, strong institutions, and financial and trade openness ameliorate the crowding-out effects and in certain instances allowed a crowding-in relationship to develop. Pradhan, Ratha, and Sarma (1988) also found that a crowding-out effect exists between private and public investment in India, although overall investment levels were higher when public investment increases. Blejer and Khan (1984) discovered evidence of a complementary relationship regarding the level of public infrastructure investment in developing economies during the 1970s, but a crowding-out effect regarding changes in the level of investment from one year to the next in their panel data analysis. Everhart and Sumlinski (2001) also found evidence of crowding-out in developing countries, with the crowding-out being especially prevalent in countries with weak

institutions. Bairam and Ward (1993), Mondadjemi (1993), and Kataoka (2002) all found evidence of crowding-out as well.

Hatano (2010) provides a template for innovative methods for determining whether a causal relationship exists between public and private investment in Japan in recent decades. Hatano employed two distinct innovations when attempting to answer the main question. First, he utilized time-series analysis techniques when evaluating the major question. Second, he attempted to answer the question by evaluating the relationship between the stock of public capital and the stock of private capital. His study found evidence of a crowding-in effect and two-way causal relationship. Ramirez (1994) found in his examination of Mexican data between 1950 and 1991 that lagged values of public investment had a statistically significant positive effect on private capital formation when utilizing time-series analysis techniques. Specifically, his findings indicated that a 10% increase in public investment generated a 2-3% increase in private investment one year later. Granger causality tests also confirmed the presence of a positive, causal relationship between public investment and future private investment. Erenburg (1993), Erenburg and Wohar (1995), Otto and Voss (1996) and Pereira (2001) found evidence of crowding-in with a VAR framework. Nakazato (2004) and Voss (2002) found no evidence that a crowding-in effect was present in the countries studied.

Atukeren (2005) produced a study relatively similar to this one, although his study utilized a transfer function model in addition to the vector error correction model that is used in

this study. His study found that crowding-out effects were present in eleven of the countries studied whereas eight countries displayed some indications of a crowding-in effect. This study also found that private investment crowded-in public investment in eleven countries while it crowded-out public investment in just two countries. Nevertheless, Atukeren' study analyzed many fewer lags of public infrastructure than this study does. Atukeren's study echoed many others, including Esfahani and Ramirez (2003), in emphasizing the role that the quality of institutions plays in determining the effectiveness of infrastructure investment in an economy.

Although any academic consensus is still best described as inchoate, the vector autoregression studies indicate that there is a crowding-out effect of public investment on private investment when contemporaneous values of each variable are controlled for. This makes sense in many regards, as there are a limited pool of funds for loans and any positive effects on private investment are unlikely to manifest themselves for a couple of years because of the lag time between the public investment, the public investment project coming on line, and any positive effect of improved private sector productivity potential as a result of a public works project.

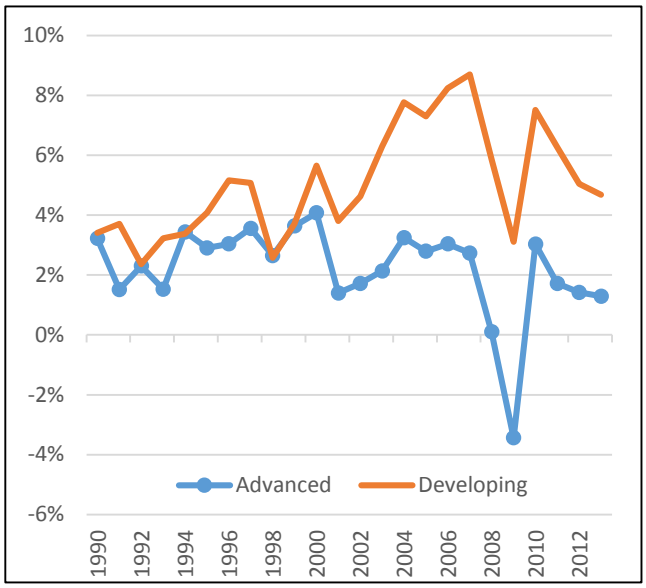
This study differentiates itself from other studies by building upon the methods and findings of previous researchers on this subject matter. In a fashion similar to Hatano (2010), it is motivated by a Cobb-Douglas aggregate production function framework, but analyzes the relationship between public and private capital using a vector error

correction model in order to account for any joint determination of the various variables controlled for in this study. This study is also unique in that it explicitly controls for and examines the lagged effects of public capital on private capital in order to more accurately and precisely determine the long-run effect of long-term investments. Finally, although a couple of other studies using vector-autoregression analysis, notably Atukeren (2005), have analyzed more than one country at a time, this study is different from most other studies analyzing the relationship between public capital and private capital by examining this relationship for dozens of individual countries instead of just one or two. This study is particularly unique in controlling for the same models for dozens of countries. Atukeren (2005) only examined an optimized model based on public capital lags. The unique combination of preexisting methods in a consistent framework provides novel insights into the relationship between public capital and private capital in developing economies.

CHAPTER 3: GLOBAL INFRASTRUCTURE ASSET GROWTH

Following a decade of weak growth between 1990 and 2000—henceforth referred to as 1990s-plus for brevity's sake—infrastructure investment increased dramatically throughout the global economy during the next ten years—henceforth referred to as 2000s-plus. During the first period of time examined, annual GDP growth in the global economy averaged 2.8%. There were marked divergences in growth performance however. High income countries grew by 2.6%, middle income countries grew by 4.0%, and low income countries grew by 2.4%. Global growth slowed down during the next ten years to just 2.6%, but this was the result of growth in high income economies decelerating to just 1.7% due to the global financial crisis. Middle income annual real GDP growth accelerated to 6.0% and low income real GDP growth accelerated to 5.4%. Similarly, there was strong growth in investment in infrastructure components between the end of 2000 and 2010 compared to the previous ten years. The remainder of this study will attempt to determine whether there is a relationship between the increase in the rate of growth in infrastructure assets in the developing world and the increase in the GDP growth rate through an increase in private investment.

Figure 2. Real GDP Growth Rates by Development Type: 1990-2013



Source: IMF

This chapter will review the growth in infrastructure endowments for four of the major forms of infrastructure: electricity capacity, water and sanitation connections, transportation networks, and telecommunication technology.

These asset endowments—and later on values—were obtained using a bottom-up analysis of nearly every developing economy around the world. The values for water and sanitation connections, transportation networks, and telecommunication technology in this section were either obtained exclusively or in some part from data in the World Bank's World Development Indicators database. Electrical capacity values were obtained from the Energy Information Administration. Household size estimates used in water and sanitation connection estimates were obtained from the Global Market Information Database.

For instances of missing data, two sets of procedures were employed. If there were between one and four years of missing asset endowment values data, the missing values were linearly interpolated.

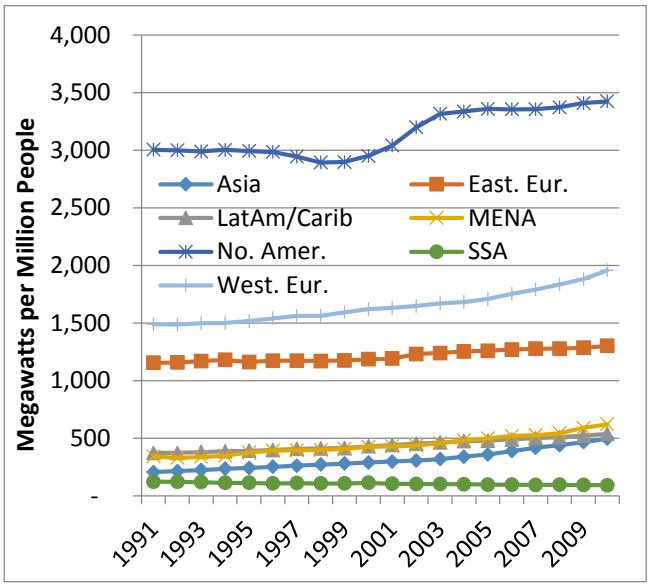
If there were five or more years of missing asset endowment values in a row, a more advanced interpolation process was employed. In these instances, the values were assigned based on the mean results of up to thirty simulations run in SAS' multiple imputation procedure. The simulated values were created as a function of 4,708 country-year panel

observations for the asset values. The missing values were estimated as a function of the past and future values of the infrastructure endowment, long-term trend economic variables, governance quality variables, population variables, time variables, and regional-income dummy variables. The mean value of the missing variables was then utilized as the endowment value going forward. Once the missing values were estimated, the total asset endowment was valued using current US dollars based on best practice per replacement unit estimate values that other studies had used previously. An extended description of this process can be found in Appendices A, B, and C.

Electricity Capacity

Possessing a sufficient base of resources and electrical capacity is one of the most important determinants of a country's growth potential. A lack of adequate access to reliable sources of electricity both results in blackouts for consumers and businesses and negatively affects investment decisions for both foreign and domestic firms, especially for developing economies. Chontanawat, Hunt, and Pierse (2008) found that electricity consumption caused GDP growth in 70% of OECD economies and 46% of non-OECD economies between 1960 and 2000.

Figure 3. Global Per Capita Electricity Capacity by Region: 1991-2010



Source: World Bank, Author's Calculations

Global energy capacity growth—including both hydrocarbon-based and renewable—lagged global GDP growth during the first decade period of study, but then grew significantly faster during the second decade examined. Middle income countries drove this growth during both periods. Energy capacity expanded in high income countries by an average of 1.5% per year during the first decade of study, which lagged real GDP growth in these countries, while capacity expanded by 2.3% between 2000 and 2010, which is a 35% faster growth rate than real GDP growth during this period. For the twenty-plus years examined, high income countries represented nearly two-fifths of overall capacity expansion. The United States alone represented over one-third of this expansion, and capacity expanded materially in Western Europe and Japan as well. Growth in all three countries/regions exceeded 40% for the period overall.

Electricity capacity expansion was particularly robust in middle income countries after 2000, with growth being especially strong after 2001. Capacity growth in the region during the 1990s-plus was 4.6%, and this growth rate accelerated to 6.7% during the 2000s-plus. Capacity growth exceeded real GDP growth during both periods of time. Overall, middle income countries represented over three-fifths of global electricity capacity expansion

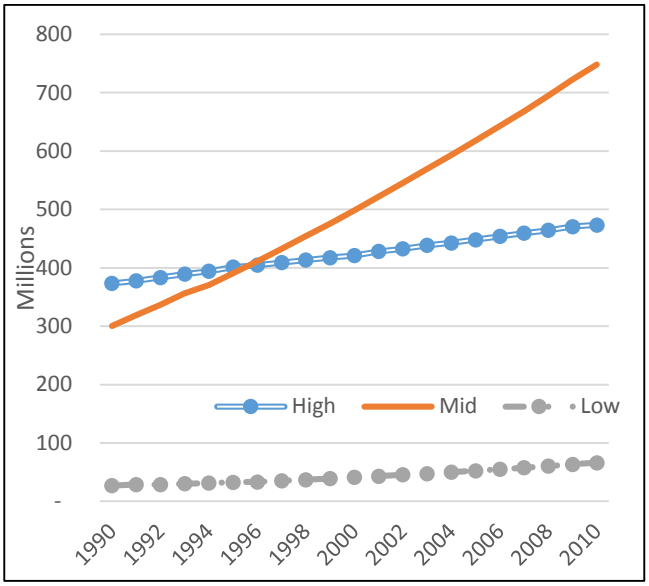
during the twenty-plus year period of examination. Capacity tripled in these regions during these two-plus decades. Chinese capacity increased by 613% between the end of 1990 and 2010, and it represented over one-third of global capacity expansion alone during this period of study. For comparison's sake, China alone added more to global electrical capacity than the combined additions in the US, Western Europe, and Japan over the same period of time. Other middle income Asian countries represented another 12.5% of total global electrical capacity expansion during this period of time. Electrical capacity expansion in low income countries was particularly weak during this period of time, with capacity growing by just 2.7% during the two-plus decades of study. Interestingly, electrical capacity growth was much stronger in the 1990s-plus in low income countries than it was during the 2000s-plus.

Water and Sanitation

While the issue is of greater relevance for developing economies than for advanced economies, where access to water and sanitation facilities is at near universal levels in almost every country, the growth in water and sanitation connections is an important signifier of developing economies transitioning towards advanced economy standards of affluence. According to Hutton and Haller (2004) at the World Health Organization, every $1 spent on improved sanitation facilities yields between $5 and $11 of economic benefits. Developing economies made remarkable strides towards increasing the share of their countries' citizens with access to improved sanitation facilities—where none of humans, animals, or insects are exposed to the excreta—during the last two-plus decades. Over this

span of time the share of East Asian and Pacific countries with access to such facilities rose by 32%-points. The comparable increase in Latin America was 13%-points, and in the Middle East and North Africa it jumped by 15%-points. By income tiers, the share of middle income populations with access to improved sanitation facilities jumped from 44% in 1990 to 74% in 2010. For the corresponding share of households with access to improved water facilities, 92% of upper middle income households had access to such facilities in 2010 while 87% of lower middle income countries had similar access. The distribution of gains in access in geographical terms were broadly similar to that which occurred with increasing access to improved sanitation facilities.

Figure 4. Number of Households with Sanitation Connection by Income Tier: 1990-2010



Source: World Bank, GMID, Author's Calculations

This improvement in access to improved water and sanitation facilities involved significant investment by governments throughout the developing world between 1990 and 2010. In particular, the number of middle income households with access to improved sanitation facilities increased by 4.7% per year over the two-plus decade span of time. Unlike many other forms of infrastructure investment, however, sanitation investment decelerated in real connection terms during the decade starting in 2001 compared to the prior decade.

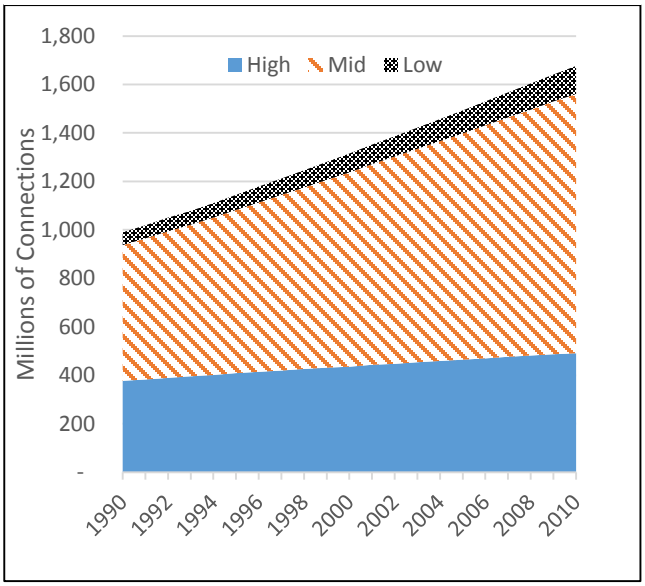
The share of the population in low income countries with access to improved sanitation facilities doubled between 1990 and 2010, going from 18% to 36%. Concerning access to improved water facilities, the share of the low income population with access to improved water facilities increased from 51% in 1990 to 66% in 2010. Additionally, the share of the population in middle income countries with access to improved sanitation facilities grew from under 37% in 1990 to nearly 60% by 2010. The share of the middle income population with access to improved water facilities jumped from 73% in 1990 to over 89% in 2010. The high income share of the population with access to improved sanitation facilities stayed in a relatively constant 95-96% ratio throughout these two-plus decades. Similarly, 98%-99% of the high income population had access to improved sanitation facilities during these two-plus decades.

Globally, sanitation connections grew faster than water connections during both the 1990s-plus and the 2000s-plus, although this largely reflects the higher base of water connections prevalent in the global economy at the beginning of the period of examination. In particular, the number of households with improved sanitation connections grew by 3.1% per year during the twenty-one years of the study while water connections grew by 2.7%. For sanitation connections, annual growth during the first ten years of the study was 3.2% while it was 3.0% during the second decade. For water connections, growth during the first decade was 2.9%, but this figure dropped to 2.5% during the second decade. Growth in high income economies largely tracked household growth over this period of time, with new connections growing by 1.2% during each two sub-periods and for the twenty-plus year period overall. New water connections also grew by 1.2% during the second period

studied, but actually grew at a slightly faster annual rate of 1.4% during the 1990s-plus. In total, high income countries represented only approximately 16-17% of total growth in new water and sanitation connections during the twenty-year period.

Middle income countries represented approximately three-quarters of the total growth in new sanitation and water connections over the previous two-plus decades. Similar to the trend seen in high income countries, average annual growth was swiftest during the 1990s-plus compared to during the 2000s-plus. Annual new sanitation connections growth averaged 5.2% and annual new water connections growth averaged 3.7% during the 1990s-plus compared to 4.1% and 2.9%, respectively, during the 2000s-plus. As was the case with many different forms of infrastructure investment, China led the way for growth in new water and sanitation connections. The country was responsible for 35% of new sanitation connections and 29% of new water connections during the two-decade-plus period. While new sanitation connection growth was relatively tepid in India over this period, the country comprised nearly 15% of total new sanitation connections across the world between 1990 and 2010. There was also robust growth in new water and sanitation connections in other middle income countries in Asia as well. In a reversal of the trend from growth in electrical

Figure 5. Number of Households with Water Connections by Income Tier: 1990-2010



Source: World Bank, GMID, Author's Calculations

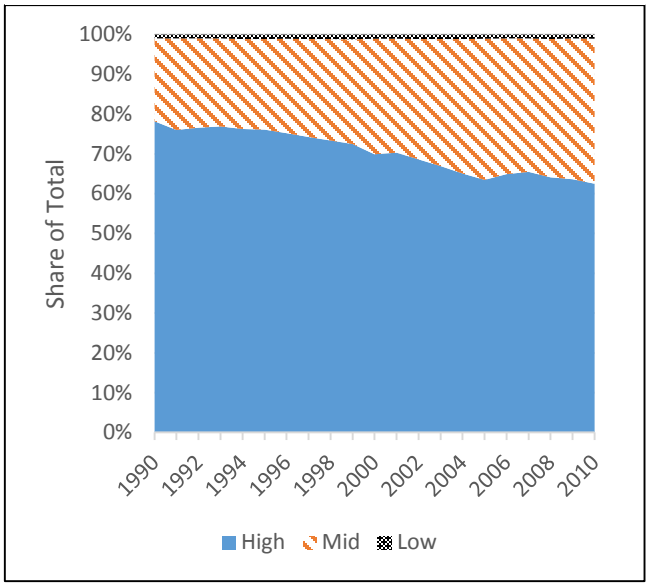
capacity, the annual growth rate in new water and sanitation connections accelerated during the 2000s-plus from the annual growth rate during the 1990s-plus, with annual growth in new sanitation connections jumping to 4.9% from 4.3% during the first period. Despite this robust growth, low income countries represented just 6.6% of new sanitation connections and 9.3% of new water connections over this period of time despite representing 16% of total population growth in the global economy.

Transportation

Infrastructure assets associated with the transportation sector—which include paved roads, railways, ports, and airports—showed divergent trends, with land-based assets growing weakly in the 1990s-plus and strong growth in the 2000s-plus, and seaport assets growing strongly during both the 1990s-plus and 2000s-plus. The sources of growth in terms of income tiers were remarkably different among the different forms of assets.

Middle income countries drove nearly three-quarters of the growth in paved road assets between 1990 and 2010, while high income countries were responsible for a little over one-quarter of the growth and low income countries were essentially a non-factor in this sphere. Nearly 80% of global paved roads were located in high income countries at the beginning of the 1990s and this share eroded to just five-eighths in 2010. This was primarily driven by weak growth in the 1990s-plus, when the length of the paved road network declined marginally in high income countries before growing by an average of 1.5% per year between 2000 and 2010. Growth in Western European paved roads was stronger in the 1990s-plus while the length of the paved road network in North America grew strongly in the 2000s-plus.

Figure 6. Distribution of Paved Roads by Income Tier: 1990-2010



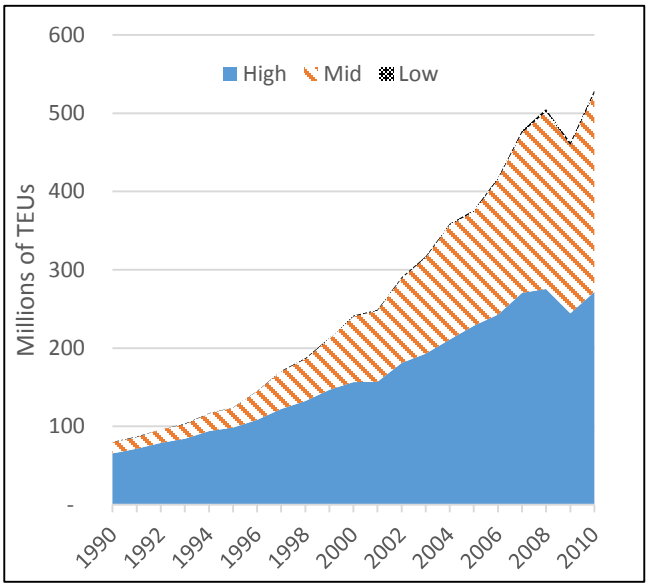
Source: World Bank, Author's Calculations

Among middle income countries, China and India dominated growth among these assets during the two-plus decade period. The two countries combined represented over 50% of total global growth in paved road stock during the two-plus decades. Other middle income countries in Asia also grew strongly while Middle Eastern and North African countries doubled their paved road network over the twenty-year-plus period. Paved road stock growth among middle income countries actually accelerated to 5.0% during the 2000s-plus

compared to 4.4% during the 1990s-plus. Overall, paved road network grew by nearly 150% among middle income countries during this twenty-year-plus period.

Port assets and traffic grew the fastest of any type of infrastructure asset over the twenty-year-plus period examined. Overall, port assets grew by 560% between 1990 and 2010, with growth split relatively evenly between high income and middle income countries. After just over 100 million TEUs (twenty-foot equivalent unit, which is an approximate measure of cargo shipped) of cargo was shipped annually in the early 1990s, nearly 530 million TEUs were shipped in 2010. Among high income countries, growth was strongest in Western Europe and high income Asian countries excluding Japan over those twenty-plus years. Annual growth was generally stronger in most high income countries and regions during the 1990s-plus compared to the 2000s-plus, with annualized growth slowing from 9.1% to 5.7%. High income countries were responsible for nearly 46% of growth in global port assets during these two-plus decades.

Figure 7. Total Port Traffic by Income Tier: 1990-2010



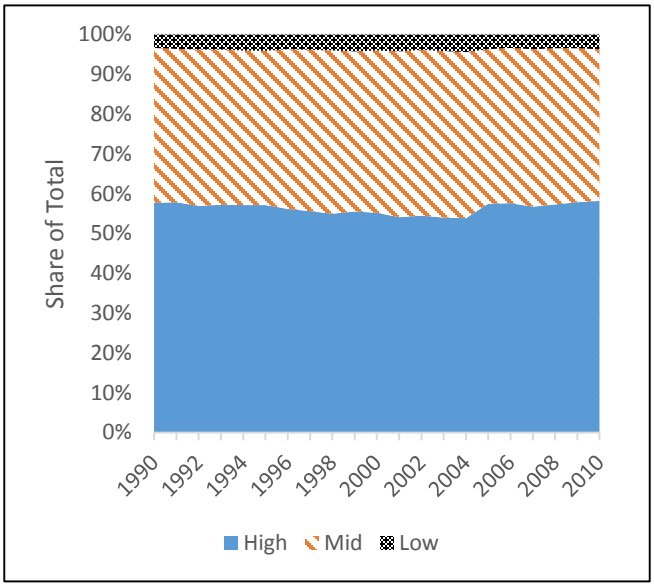
Source: World Bank, Author's Calculations

Compound annual growth in middle income country port assets was a scintillating 15.4% per year on average between 1990 and 2010. China, not surprisingly, drove over half of middle income growth during this period, and had annual growth rates of 43% and 12% during the 1990s-plus and 2000s-plus, respectively. Other middle income Asian countries excluding India drove over 11% of total global growth during this period while middle income Latin American countries comprised nearly 7% of total global growth during this period. Overall, middle income countries drove around 53% of global growth in port assets and traffic during this twenty-year-plus period and represented around 48% of total assets/traffic by the beginning of the 2010s. Low income countries drove just 0.7% of total growth in global port traffic during this period.

Rail assets in the form of functioning rail tracks were one of the few types of assets to see a decline in value over the course of the 1990s, and unlike most forms of infrastructure assets high income countries drove the majority of growth in asset formation between 1990 and 2010. Between 1990 and 2000, annual growth in the length of the global rail network was -0.6% before rebounding to 1.4% between 2000 and 2010. High income countries were responsible for a little under two-thirds of the sector's growth during this period, with North America driving more than 100% of total high income growth because of declines in practically every other major high income region outside of Australia over this twenty-one-year period. Overall, high income rail stock grew by 8.6% during the twenty-year-plus period, and the share of total rail assets rose from 57.7% in 1990 to 58.2% during 2010. This was the only infrastructure subsector that saw a growth in the high income share of assets between 1990 and 2010.

Middle income rail networks grew by a little under 6% between 1990 and 2010, and expanded by a relatively robust 0.7% per year during the 2000s-plus. All told, middle income countries were responsible for 29% of the global growth in rail assets during this twenty-one-year period. Brazil drove most of the growth of rail assets in middle income countries, and the network expanded by nearly twice as much in absolute terms as China between 1990 and 2010. Similar to its high income peers, the rail stock in middle income Eastern European countries contracted over this two-plus decade sample. The rail network contracted in other middle income Latin American countries, India, and middle income Sub-Saharan African countries over the period of study as well. In terms of total growth between 1990 and 2010, low income countries actually grew their rail network the most of all three income tiers at 17.3% between 1990 and 2010. Given the low 3.4% of installed rail capacity at the beginning of the 1990s, however, the growth in low income rail network comprised just 7.5% of growth in the global rail network during the two-plus decades examined.

Figure 8. Distribution of Rail Track by Income Tier: 1990-2010



Source: World Bank, Author's Calculations

Telecommunications

The amount of telecommunications-related assets has exploded since 1990, although growth leadership has shifted throughout the period. Traditional fixed telephone lines grew the strongest during the 1990s when cellular phones were just an emerging technology and broadband Internet connections were merely in the development phase. During the 2000s growth in the telecommunications industry was spurred by the need to build out networks for cellular telephones, with many countries seeing the number of cellphone subscriptions dwarf the number of fixed telephone lines in operation by the beginning of this decade. By the beginning of the 2010s, the number of broadband subscriptions began to grow dramatically and spur a new round of asset buildup to facilitate this dramatic increase in demand on the existing telecommunications network. The composition of growth leadership differed dramatically within the three types of telecommunication assets.

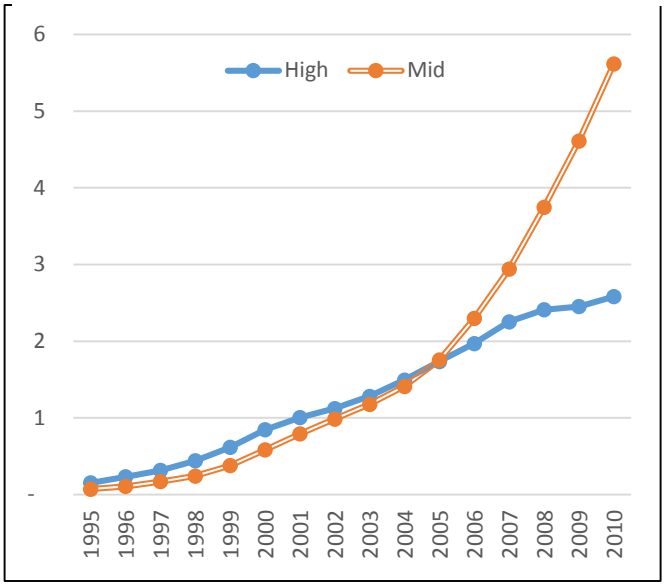
Somewhat unexpectedly given that there are nearly six cell phone subscriptions for every fixed telephone line in middle income countries compared to a little under three in high income countries, middle income countries were the primary growth drivers in the build out in telecommunication assets related to new fixed telephone lines. High income countries represented a little over one-fifth of the growth in total fixed telephone lines during this two-plus decade period, although the number of fixed telephone lines in operation actually declined from over 600 million lines in 2000 to just 572 million lines in 2010. The United States drove the major trends during both periods, with annual average growth of 3.6% during the 1990s-plus and an annual average contraction of 2.6% during

the 2000s-plus. Western Europe's growth and contraction over the two periods was less dramatic than the one seen in the US, while Japan's fixed telephone line connection base grew moderately during both periods.

In fact, middle income countries comprised nearly 80% of the growth in new fixed telephone line-related assets, with annual growth of nearly 11% between 1990 and 2010. Unsurprisingly, there was a much faster adoption of these assets in the 1990s-plus (15.7% per year) than in the 2000s-plus (5.9% per year) before cellular phone networks were built out in many developing economies. China and other middle income Asian countries excluding India alone represented over half of total growth in new fixed telephone lines. Middle income Middle Eastern and North African countries also rapidly built out their fixed telephone networks during this period. The per year growth in fixed telephone lines was the fastest in low income countries during the 2000s-plus, but their low base of installed lines meant that these countries represented just 1% of the growth in such assets over the two-decade-plus period.

Growth leadership in the build out of telecommunications networks due to new mobile phone subscriptions was also driven by middle income countries between 1990 and 2010, but high income countries and low income countries comprised larger shares of growth in cell phone-related assets than they did with fixed telephone lines. Among high income countries, Western European countries were the primary growth driver of new cell phone-related network assets. The region represented 9.5% of the total global growth in new cell phone-related assets between 1990 and 2010, and the region had over 500 million subscriptions by the beginning of this decade. Japan and other high income Asian economies also grew their mobile phone-related assets at a rapid clip during these two-plus decades. By contrast, the United States represented just 5.3% of the growth in new cell phone-related assets over the same time period. Canada also grew its cell phone network at a below average rate during this time period despite being home to one of the most prominent cell phone makers, Research in Motion.

Figure 9. Ratio of Mobile Phone Subscriptions to Fixed Telephone Lines by Income Tier: 1995-2010



Source: World Bank, Author's Calculations

Similar to many forms of infrastructure assets, middle income countries drove a decided majority of growth in cell phone subscriptions—here over two-thirds of new subscriptions—but the composition of growth within regions was much more egalitarian

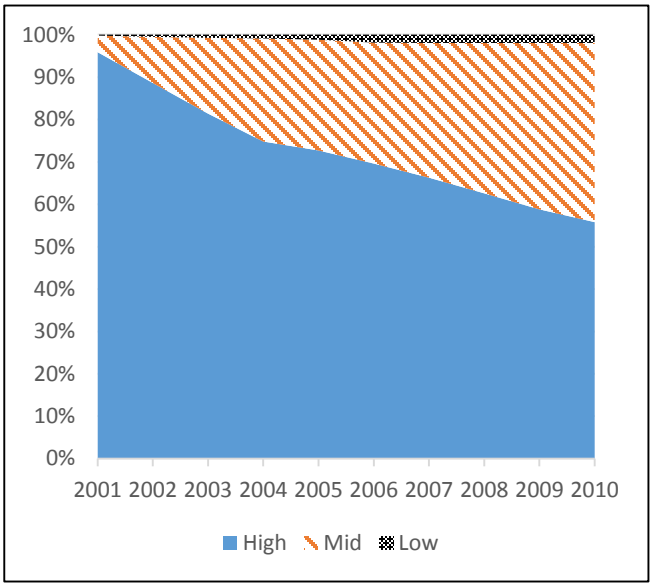
than it was for other types of assets. Whereas China comprised between 28% and 42% of practically all other forms of infrastructure assets discussed so far with the exception of new rail lines[1], the country was responsible for just 16% of new cell phone subscriptions around the world between 1990 and 2010. Growth was strong in other middle income countries, with India and other middle Asian income countries, such as Indonesia, Malaysia, and the Philippines, representing 14.3% and 14.2%, respectively, of total global growth during this period. Brazilian growth was stronger than other middle income Latin American countries, while growth was above average in middle income Eastern European, Middle Eastern and North African, and Sub Saharan African countries. Low income countries represented a much more robust 5.1% of total global growth in new cell phone subscriptions, and there were nearly thirty cell phone subscriptions for every fixed telephone connection at the beginning of this decade in low income countries.

Unlike many other forms of infrastructure assets, high income countries were responsible for a majority share of the growth in installed broadband connections rather than middle income countries. In total, 57% of new broadband connections between 1990 and 2010 were installed in high income countries. Western Europe was responsible for the largest share of new assets, as this region represented in excess of one-fifth of total growth in these assets globally during the time period. The US, by contrast, represented a little under 16%

[1] Even with new rail lines, it is quite possible that China's growth is understated by official World Bank figures, as certain Chinese railroad agencies list the kilometers in operation in excess of 90,000, although official World Bank figures are used in this report.

and Japan comprised a little over 6%. Other high income Asian economies also grew their broadband networks at an above average rate during this time period.

Figure 10. Cumulative Share of Growth in New Broadband Connections by Income Tier: 2001-2010



Source: World Bank, Author's Calculations

China dominated the growth in broadband connections among middle income economies between 1990 and 2010. The country alone represented nearly three-fifths of total growth in broadband connections during this time period. India was a relative laggard, especially compared to its rapid adoption of new cell phone subscriptions, and the country did not even have 10 million broadband connections by the end of the last decade. Among other middle income regions, other middle income Asian economies and Middle Eastern and North African economies grew at strong rates. Low income countries represented just under 2% of growth in new broadband connections globally.

Infrastructure Asset Growth and Private Investment

The surge in the growth of infrastructure assets in the developing world—a large majority of which were built by public entities based on a comparison of the growth in total

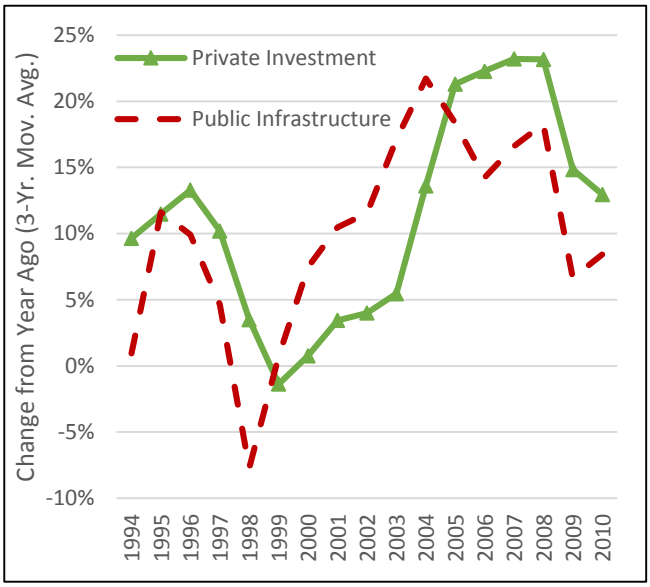
infrastructure assets and privatization investment flows in these sectors—occurred during a period of structurally declining gross capital stock growth rates in the advanced world and accelerating gross capital stock growth rates in the developing world. While the global gross capital stock growth rate has been decelerating in real terms for three decades, it accelerated dramatically in developing countries. The real gross capital stock growth rate in the advanced world went from 3.8% during the 1980s to 3.2% during the 1990s and 2.7% during the 2000s. By contrast, after declining to a growth rate of 3.9% during the 1990s following a growth rate of 4.3% during the 1980s, the real gross capital stock growth rate of developing economies surged to 5.5% during the 2000s. Furthermore, for all low income countries, the real growth rate for private capital stock accelerated from 5.3% during the 1990s to 6.4% during the 2000s. For lower middle income countries, the growth rate acceleration was less pronounced, but the real private gross capital stock grew by 7.4% during the 2000s compared to 6.7% during the 1990s.

Infrastructure asset growth and private investment[2] growth in developing economies had similar growth trajectories during the 1990s-plus and the 2000s-plus. Between 1990 and 2000, the private sector's gross fixed capital formation share of GDP averaged 15.2% for the developing countries where data was available. During the next ten years, this figure jumped to 16.7%. Given that GDP growth accelerated in the 2000s-plus, and assuming that the private sector share figure for available countries is representative of low and middle

[2] In this study, there is no differentiation between foreign direct private investment and endogenous private investment. While material amounts of FDI might reduce the domestic profitability of total private investment, the simplifying assumption is that both domestic and foreign private investment receive similar returns to growth.

income countries as a whole, this implies that private sector gross fixed capital formation went from growing under 6% per year in nominal terms during the 1990s-plus to 14.5% during the 2000s-plus. Similarly, based on per unit pricing valuations by leading non-governmental organizations such as the World Bank and based on private sector investment volumes in infrastructure projects in low and middle income economies[3], public sector infrastructure assets—which represented between 93% and 99% of total infrastructure assets in these economies over these two-plus decades—grew by 3.6% per year between 1991 and 2000 before jumping to 13.4% per year between 2000 and 2010 in nominal US dollar terms.[4]

Figure 11. Growth Rate of Private Investment and Public Infrastructure Spending in Developing Economies: 1994-2010



Source: World Bank, IMF, Eurostat, BEA, EIA, Author's Calculations

The comparisons become increasingly interesting when broken down by specific income groups within developing economies. The relationship between the timing of growth in the level of the public infrastructure stock and growth in the private capital stock, including

[3] For this derivation, see Appendices A, B, and C

[4] This portion of the study uses nominal terms due to the limitations of available data for public-private infrastructure spending by developing countries. Chapters 4, 5, and 6 analyze private and public capital stocks in real terms, but it should be noted that inflation consistently declined during the 1990s and 2000s in developing economies, so it is not a factor that caused the acceleration in capital stock growth rates during the 2000s relative to the 1990s.

residential housing stock, is of particular interest because of possible indications of a causal relationship between the two series. While low income countries display a relatively synchronized relationship between growth in the private capital stock and public infrastructure capital stocks, both lower and upper middle income countries indicate that there is a leading relationship between growth in the public infrastructure capital stock and growth in the private capital stock. For both lower and upper middle income countries, the correlation between three-year moving average annual growth rates of public infrastructure capital stocks and private capital stocks is strongest when there is a two year lead between increases in the public infrastructure capital stock and the future values of private capital stock. When all developing countries are controlled for, the correlation between the two data series is above 90% for both two and three year lags of public infrastructure capital stock and the private capital stock, and the correlation is above 80% for both one year and four year lags as well.

Table 1. Correlation between Public Infrastructure Capital Stock and Private Capital Stock Growth Rates among Developing Countries over Three Year Periods by Public Infrastructure Capital Stock Lag: 1993-2010

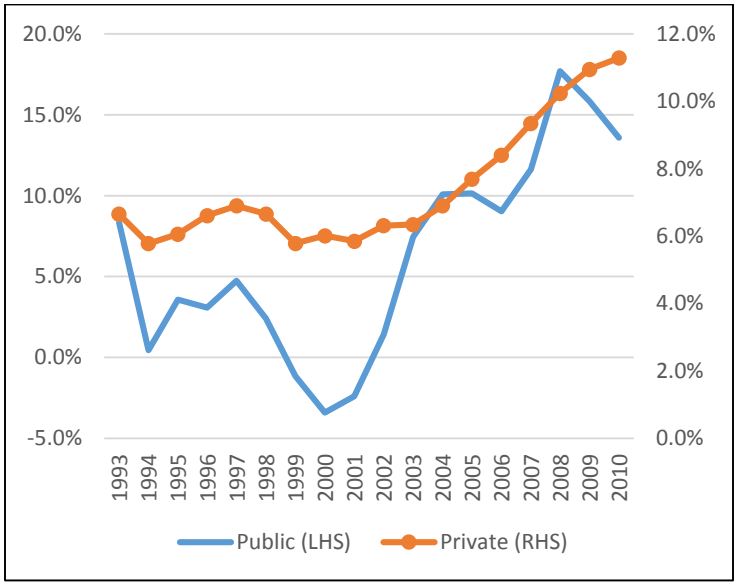
Public Capital Stock Lag	Low Income	Lower Middle	Upper Middle	Developing Countries
Simultaneous	87%	75%	51%	61%
One Year	86%	90%	77%	84%
Two Year	82%	94%	89%	95%
Three Year	74%	87%	86%	92%
Four Year	63%	71%	74%	80%
Five Year	48%	41%	49%	55%

Source: World Bank, IMF, Eurostat, BEA, EIA, Author's Calculations

All three developing country income groups showed an acceleration in public infrastructure capital stock and private capital stock growth rates in the 2000s-plus compared to the 1990s-plus.

For low income countries, the public infrastructure capital stock grew by 2.4% per year during the 1990s-plus while the private capital stock grew by 6.4% per year. During the 2000s-plus, the annual growth rate of the public infrastructure capital stock accelerated to 10.9% while the private capital stock growth rate jumped to 8.8% per year.

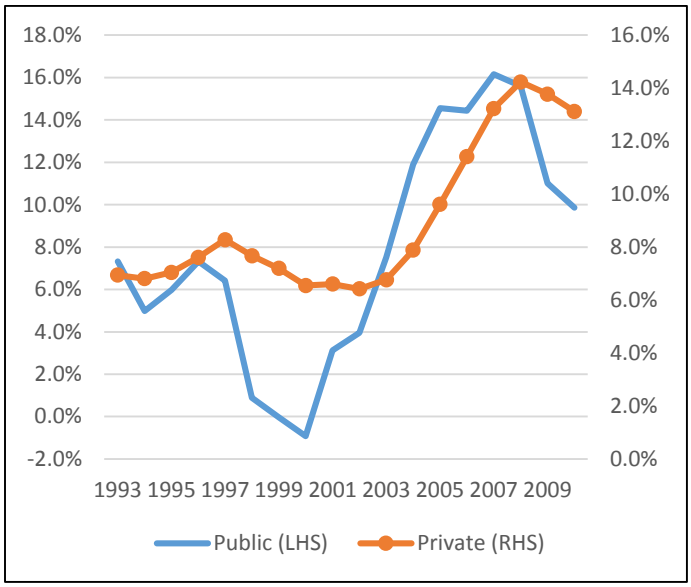
Figure 12. Annualized Growth Rates of Public Infrastructure Capital Stock and Private Capital Stock over Three Year Periods for Low Income Countries: 1993-2010



Source: World Bank, IMF, Eurostat, BEA, EIA, Author's Calculations

For lower middle income countries, the private capital stock grew by 7.2% per year during the 1990s-plus before accelerating to 10.9% during the 2000s-plus. Similarly, the public infrastructure capital stock for this income class grew by 11.6% per year during the 2000-plus after growing by just 4.7% per year during the 1990s-plus.

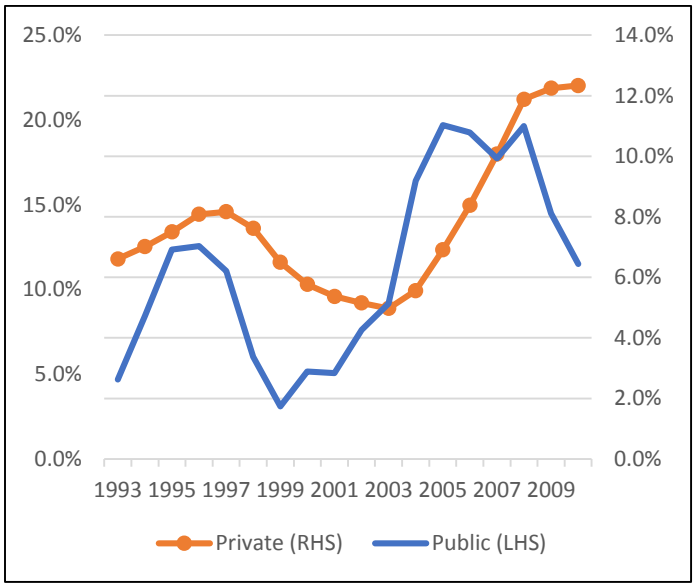
Figure 13. Annualized Growth Rates of Public Infrastructure Capital Stock and Private Capital Stock over Three Year Periods for Lower Middle Income Countries: 1993-2010



Source: World Bank, IMF, Eurostat, BEA, EIA, Author's Calculations

Upper middle income countries displayed a similar pattern between the growth rates of the private capital stock and the public infrastructure capital stock during the two most recent decades. The annual private capital stock growth rate in this income class was just 6.9% during the 1990s-plus while the public infrastructure capital stock growth rate was just 7.3%. During the 2000s-plus, the public infrastructure capital stock growth rate jumped to 13.9% while the private capital stock growth rate also accelerated to 8.9% during this period.

Figure 14. Annualized Growth Rates of Public Infrastructure Capital Stock and Private Capital Stock over Three Year Periods for Upper Middle Income Countries: 1993-2010



Source: World Bank, IMF, Eurostat, BEA, EIA, Author's Calculations

The strong lagging-leading relationship between the private capital stock and public infrastructure capital stock among developing economies demands more rigorous analysis in order to determine if there is a causal, crowding-in relationship between the two series. Determining if there is a causal and crowding-in relationship between public and private capital stocks is the focus of the next three chapters.

CHAPTER 4: METHODOLOGY

Part 1: Methods Discussion

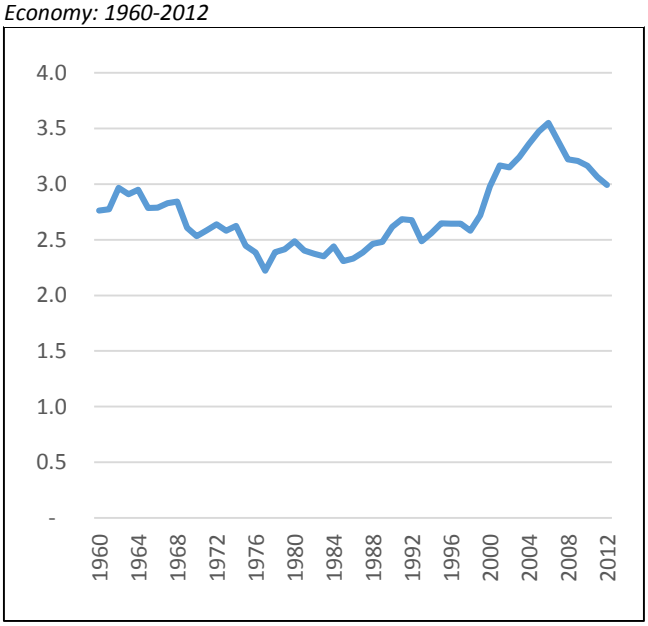
As discussed previously, most studies that have investigated this subject previously have done so using cotemporaneous values of private and public capital, panel data analysis techniques, and growth rates of public and private capital, each of which contains material structural flaws inherent in the construction of the model. This part examines the primary flaws in these models before introducing the approach pursued in this study.

Models based on contemporaneous measures of private and public investment—either in flows or stock—are inherently likely to show a negative relationship between public and private investment. There will always be a lag between when construction begins on a public investment project—such as a new highway, expansion of power capacity, or new water and sanitation facility, to name just a few—and when the private sector can start benefitting from this addition to the capital stock. This is especially the case for non-infrastructure public investment projects—such as new schools or hospitals—where the lag time between when breaking ground occurs and when the benefits accrue to the private sector can just as easily be measured in decades as it can in years. Even though it is likely that some preparation work by private firms will have already been completed by the time construction begins on a new public investment project, there is still the not insignificant amount of time needed to fully construct the public project and account for any deviations from original intent that occurs during the construction process as a result of unforeseen

factors that arise. This is not universally the case as certain private sector investment projects, such as new commercial and residential construction, can synchronize their construction process with traditional infrastructure projects.

Furthermore, while data indicate that the pool of credit in advanced economies is quite deep in terms of share of GDP, it is generally much shallower in developing countries, which are the focus of this study. Between 1960 and 2012, domestic credit to the private sector in advanced economies as a share of GDP was consistently 2.5 to 3.5 times larger in advanced economies compared to developing economies based on World Bank data. Given the relatively shallow pool of available credit for the private sector in many developing countries, it is not surprising that some zero-sum allocation decisions exist for the financial sector in these economies that reduce the pool of savings available for private investment in a given year. The key question with regards to public infrastructure projects is whether the public project expands the universe of investment opportunities for the private sector once the project is constructed above and beyond what would have existed in absence of the public infrastructure project. Studies that are based on contemporaneous allocations of

Figure 15. Ratio of Advanced Economy Domestic Credit to the Private Sector as a Share of GDP Compared to Developing Economy: 1960-2012



Source: World Bank, Author's Calculations

private and public infrastructure flows tend to be structurally incapable of answering that question.

Additionally, studies that use panel data econometric techniques when attempting to comment on primarily time-series data sets create a host of methodological concerns. Panel data was originally conceived for large samples of different entities (people, countries, animals, etc.) over relatively short spans of time. The original practitioners of such theories employed models with asymptotic statistical theories where the number of entities could move towards infinity for a fixed amount of time according to Smith (2001). Many recent studies on the subject of the effect public infrastructure projects—either stocks or flows—have pooled the values of dozens of countries over multiple decades, which runs contrary to the original intent of panel data analysis. This is especially so when stocks are measured, as in most countries the stock value of private and public capital is decidedly non-stationary. In such circumstances, an order of integration or cointegration needs to be determined for a linear combination of variables in order to make sure that equilibrium or arbitrage conditions imply stationarity, I(0). If such a process is not implemented, the findings are spurious. While it may be possible that in certain cases this process occurred, the text of many of these studies did not elaborate on the process implemented to control for such concerns at great length. Additionally, with the exception of instrumental variable panel data analysis, most panel data analysis techniques assume an exogenous relationship between dependent and independent variables that may not be justified. Given the increasing availability of reliable time-series data for multiple data series in both advanced and developing economies, time-series data analysis techniques are preferred barring

unforeseen factors that make such analysis suboptimal assuming panel data specifications and techniques are not modified to account for the presence of data for longer time periods for individual countries in different studies.

Finally, the use of stocks as the unit of measurement for both private and public capital is preferred relative to flows as it allows researchers to hone in on the question of what helps a developing economy become an advanced economy. The use of stocks also allows researchers to control for the possibility of diminishing returns once a country's private and/or public capital stock reaches a certain threshold relative to the size of the population. Given that much of the intent of researching the determinants of private capital formation in both developing and advanced economies is meant to see what allows a country to move from developing status to advanced status—where real GDPs per capita are many multiples higher on average compared to developing economies—it makes more sense to evaluate the drivers of the stock of private and public capital since that provides a uniform baseline across countries—when population is also controlled for—that makes comparison against multiple countries more fruitful in terms of drawing useful insights from research on the subject.

For the reasons stated in the preceding paragraphs, time-series methods, stock values of private and public capital, and lagged values of public capital are used in this study. Additionally, data series will either be differenced and/or cointegration controls will be implemented depending on what the optimal specification is for individual countries.

While previous methods may have been more appropriate when the availability of time-series data for many developing and advanced economies was more constricted, recent advances in the availability and quality of time-series macroeconomic data make the use of time-series techniques possible. Given the superior properties and ability to avoid methodological issues associated with panel data analysis, multivariate time series are used to answer the key questions in this study. The particular technique used is the vector error correction model, which addresses concerns about stationarity and adjusts for cointegration ranks within individual countries' time series. It also accommodates and adjusts for endogenous relationships between variables when warranted.

Part 2: Data Sample and Variables Studied

A large share of data for this portion of the study came from the World Bank's World Development Indicators Database. All values for population, gross domestic product, private and public gross fixed capital formation—from which capital stocks were created after depreciation rates were controlled for—and domestic credit to the private sector were obtained directly from or derived exclusively from data form the World Development Indicator's database. Values for Economic Freedom ("Freedom") were taken from the Fraser Institute's Economic Freedom of the World Database. Values for the Chinn-Ito Index ("Openness"), which is a proxy for a country's level of financial openness, came from a spreadsheet located on Prof. Hiro Ito's personal webpage. Once some selective, judicious interpolation was implemented, twenty-four countries had usable time series—at

least twenty consecutive years—from which conclusions could be drawn. In total, 660 country-years of observation were available, or an average of 27.5 years per country.

Private capital stock estimates, which include private residential housing stock, were created using data from the World Bank's World Development Indicators Database and the perpetual inventory method for the creation of the stock value. The World Bank provides data directly for the private sector share of gross fixed capital formation in a country in a given year as a share of GDP. This figure is converted to constant 2005 US dollars and considered the flow of investment. Although multiple formulas for estimating initial capital stock exist, this study used the "disequilibrium" formula due to the fact that all countries examined were far from their steady states. The depreciation rate varied over time based on the work of Berlemann and Wesselhöft (2012), but generally revolved around 4% with the rate increasing over time. The value of the public capital stock was obtained in a similar fashion, with the investment flows in a given year being equal to subtracting the private sector gross fixed capital formation as a share of GDP from the total gross fixed capital formation as a share of GDP in that country. For the remainder of this study, public capital stocks include both the traditional public infrastructure capital assets as well as the non-infrastructure public investment projects such as schools and hospitals. Private capital stocks, and specifically what causes them to grow, are the focus of this study. Whether increases in the stock of public capital is the key question in this study. Thus, both variables are included in this study.

Population and the size of the economy are controlled for in this study in order to determine whether the size of a country's private capital stock is partially affected by the size of the populace and/or the economy as a whole. Both values are taken directly from the World Bank's World Development Indicators Database.

Previous studies such as Erden and Holcombe (2005), Blejer and Khan (1984), and Erden and Holcombe (2006) have found that the depth of financing opportunities available to private sector entities in a country is more important than the rate of interest that private sector entities pay. Thus, this variable is controlled for in order to determine whether this relationship holds up when time series techniques are used and for developing countries, where the levels of credit to the private sector are materially lower than the prevailing levels in most advanced economies. All values for this variable come directly from the World Bank's World Development Indicators Database.

Many previous studies, such as Atukeren (2005), have found that the quality of institutions in a country are important in determining the wealth of a country. Thus, this study includes the value of the Fraser Institute's Economic Freedom, which the Fraser Institute states attempts to measure the degree to which policies and institutions within countries are supportive of economic freedom as a function of personal choice, voluntary exchange, freedom to compete, and security of privately-owned property. All values are taken directly from the Fraser Institute's Economic Freedom of the World Database, with values interpolated between 1970 and 1975, 1975 and 1980, 1980 and 1985, 1985 and 1990, 1990

and 1995, and 1995 and 2000. This statistic provides a consistent, well-regarded route for controlling for the quality of institutions over the last four-plus decades when attempting to determine whether institutions affect the formation of private capital in countries.

The level of financial openness, which in many ways is used as a proxy for whether a country is open to global trade and the attendant competitive pressures such openness places on domestic firms, is included to control for whether firms in developing countries respond to competitive pressures by increasing their technological capabilities. The variable is formed by a first principle component process from variables pertaining to capital account openness, exchange rate uniformity, and trade freedom. All values for this variable are obtained directly from Prof. Ito's personal webpage at Portland State University[5].

Part 3: Underlying Theoretical Model

As Hatano (2010) hypothesized, it is difficult to imagine a country—especially a developing country—possessing a surfeit of private capital with just a modicum of public capital. Without electrical power and transportation facilities, which are traditionally supplied by public entities in developing economies, private firms would be unable to produce their goods and deliver them to domestic and foreign markets. Countries without water and sanitation facilities would require the citizenry to expend an enormous amount

[5] This index can be found at the following URL: http://web.pdx.edu/~ito/Chinn-Ito_website.htm

of time procuring those services on their own. Finally without modern telecommunications facilities, domestic firms would be unable to compete against foreign competition, which by and large does have access to such facilities. Thus, an appropriate theoretical framework to model the growth of private capital stock over a long period of time should be centered on the hypothesis that there is a positive two-way relationship between the stocks of private and public capital and controls for potential lagged effects between public capital and private capital. Indeed, this study's a priori hypothesis is based on the findings from Aschauer (1989) that there is a crowding-in effect of public capital on private capital through an increase in the marginal product of private capital.

The base model utilized in this study is a Cobb-Douglas production function that disaggregates private and public capital. It is a slight variation of the model Hatano (2010) utilized,

$$Y_t = A_t L_t^{\propto} K^{\beta}{}_{t-1} K G_{t-1}^{\gamma} \quad (1)$$

Where *Y* measures real aggregate output, the subscript *t* represents the particular year examined, *A* is a measure of productivity, *L* the aggregate labor input, *K* aggregate private capital, *KG* aggregate public capital, and α, β, and γ are parameters.

As Hatano (2010) explained, with a reordering and manipulation of the production function in (1), $\beta Y_t/K_{t-1}$ is the marginal product of private capital and $\gamma Y_t/KG_{t-1}$ is the marginal

product of public capital. The assumption that follows from this relationship is that prevailing interest rates will be equivalent to both marginal products in an environment where private and public sectors accumulate capital in a properly functioning market optimally. Given that the private and public sectors are charged different interest rates, however, it is appropriate to create two separate equations to denote the interest rates that are charged for the government (*r*) and private sector (*q*), which we compute as equal to these respective marginal products:

$r_t = \gamma Y_t / KG_{t-1}$, $q_t = \beta Y_t / K_{t-1}$

As Hatano (2010) explains further, if one assumes that the market is able to perfectly price risk, then arbitrage opportunities will either exist for only negligible amounts of time or will never exist. Thus, a constant relationship/ratio (θ) between the interest rates charged to the public and private sectors is hypothesized, which allows for the relationship between private and public capital formation to be rewritten as follows:

$K_t \sim (\frac{\beta}{\theta\gamma}) KG_t$ (2)

If the assumption that the marginal products or public and private capitals are constant, which is embodied in an environment where private and public capital formation occurs at optimal rates, then θ=1. When a country reaches a steady-state environment and in an environment where private and public capital is allocated optimally, the two types of capital will grow at an equivalent rate. However, given that all countries examined in this

report are still developing, it is not expected for the growth rates between the two series to be equivalent.

Cointegration Analysis

With the model for the two primary variables of interest created, the next step was to determine whether the private capital stock was a stationary time series or not. Given that the real private capital stock increased materially in every country besides Burundi and Cote d'Ivoire during the time periods examined, the a priori hypothesis was that the real private capital stock data series would be a non-stationary data series, and thus require the specification of cointegrating relationships with the other variable studied. Not surprisingly, analysis showed that practically every country was non-stationary at the 10% level of statistical significance when the undifferenced time series was tested for stationarity for all three types of Augmented Dickey-Fuller (ADF) Unit Root Tests. Most, although not all, countries would achieve stationarity after a first or second differencing in one of the three types of ADF Unit Root Tests. Given that multiple variables would be tested in the final models for the determinants of the stock of private capital in a developing country and that there was strong reason to believe that there would be more than one cointegration vector for data series in any given country, the stationarity tests were not conducted. If there was only one variable of interest, as opposed to of primary interest, a stationarity test would also have been conducted.

Table 2. Results of Augmented Dickey Fuller Tests for Countries in Sample

Country	No Differencing		First Differencing		Second Differencing	
	Unit Root?	White Noise?	Unit Root?	White Noise?	Unit Root?	White Noise?
Algeria	Yes	No	No	Yes	No	No
Bolivia	Yes	No	Yes	no	No	No
Burundi	No	No	No	no	No	No
Cameroon	Yes	No	Yes	no	Yes	No
DRC	Yes	No	Trend	yes	No	No
Cote d'Ivoire	Yes	No	Trend	yes	No	No
Fiji	Yes	No	Yes	no	Yes	No
Gabon	Yes	No	Trend	yes	Trend	No
Ghana	Yes	No	Trend	No	Trend	No
Iran	Yes	No	Trend	no	Trend	No
Malawi	Trend	No	Yes	no	Trend	No
Malaysia	Trend	No	No	no	No	No
Mexico	Yes	No	Yes	no	Trend	No
Morocco	Yes	No	Trend	yes	Trend	No
Nicaragua	Yes	No	Trend	no	Trend	No
Pakistan	Trend	No	Yes	no	Trend	No
Philippines	Yes	No	Yes	no	Yes	No
Sierra Leone	Yes	No	Yes	yes	No	No
South Africa	Yes	No	Yes	no	No	No
Togo	Yes	No	Trend	no	Trend	No
Trin. & Tob.	Yes	No	Yes	no	Yes	No
Tunisia	Yes	No	Yes	no	Yes	No
Uganda	Yes	No	Yes	no	Yes	No
Uruguay	Yes	No	Yes	no	Yes	No
Zambia	Yes	No	Yes	no	Yes	No

Source: Author's Calculations

Once the non-stationarity of the private capital stock series was established[6], the optimal model to utilize when evaluating the statistical significance of various explanatory variables, including the stock of public capital, bank credit as a share of GDP, Economic Freedom, the Chinn-Ito Openness Index, the size of the population, and the size of the country's economy, had to be determined.

Given the expected two-way relationships between many of the variables examined in this study, six vector error correction models were constructed for every country in this study. These models included the contemporaneous[7] values for every explanatory variable and six different lags for the public capital stock controlled for in order to allow for a delayed effect between the public investment project's construction and any effects on the level of private capital stock. Before final models were evaluated however, Johansen tests were conducted in order to identify and implement the proper cointegrating relationships. Once those tests were conducted and models adjusted to correct for the proper cointegrating relationship, where possible, the model was re-run and results examined. Given that the sample size for many of the countries examined was relatively small—anywhere between the high teens and mid-thirties—many of the models were not able to achieve full rank during the cointegrating process, especially when the contemporaneous or one-year lag of public capital stock was the unit of measurement in the model specification.

[6] Burundi was thrown out given the unacceptable behavior of the capital stock series, as after depreciation is factored in many of the yearly results showed negative levels of capital stock.
[7] The way that vector error correction models function essentially entail a one-year lag on the explanatory variables in the study, but further lags were nonetheless deemed appropriate for reasons discussed earlier in the thesis.

CHAPTER 5: CAUSALITY TEST RESULTS

Results for Variable of Interest

In attempting to identify whether changes in public capital either crowds-in, crowds-out, or has no effect on private capital formation, a full model had to be created. In addition to the real public capital stock, other potential explanatory variables needed to be controlled for in order to make sure that the public capital stock's effect on the changes in real private capital stock is not picking up the effects of other variables as much as possible. Thus, Chapter 5 will examine whether the real public capital stock and additional potential explanatory variables have a causal effect on private capital stock and vice versa. If a sufficient share of countries show a causal relationship in at least one direction over 70% of the time for at least one specification, they will be included in the final tests that analyze the effect that public capital formation has on private capital formation once other key explanatory variables are controlled for in this study.

While the results of the various tests for causality generally support the hypothesis of two-way causality between private and public capital, the results contain enough caveats that definitive declarations are not yet formable when it comes to the relationship between the stocks of private and public capital in developing countries. The specific Granger Causality test being conducted in each table in this chapter is best represented by the following null and alternative hypotheses:

$$H_0: Changes\ in\ the\ explanatory\ variable\ do\ not\ Granger - Cause\ changes\ in\ the\ level\ of\ the\ private\ capital\ stock$$

$$H_a: Changes\ in\ the\ explanatory\ variable\ do\ Granger - Cause\ changes\ in\ the\ level\ of\ the\ private\ capital\ stock$$

All twenty-two countries that were able to achieve full rank status during the cointegrating process for at least one of the six models showed a causal relationship between the stocks of private and public capital over the period of examination. Nearly 70% of countries showed a causal relationship between changes in the level of public and private capital stock in at least half of the models tested for which full rank status was attained. Somewhat surprisingly, there did not appear to be a lagged relationship between public capital and private capital in these models in terms of causality either way, although far fewer models were able to achieve full rank when public capital was either contemporaneous or just contained one lag.

The results for the Granger Causality tests determining whether changes in the level of private capital stock causes changes in the level of the public capital stock were far less conclusive. Interestingly, while the average number of years of causality for the countries that produced at least one year where changes in the level of the private capital stock caused changes in the level of the public capital stock were equivalent to the average years of causality for the countries that produced at least one year where changes in the level of the public capital stock caused changes in the level of the private capital stock (both 2.4 years).

Only nine of the seventeen countries that were able to achieve full rank status and pass a cointegration rank test had at least one year where past private capital caused public capital formation depending on the lag for private capital. Additionally, no definitive relationship between the lag of private capital and the likelihood of causality exists. Thus, while it cannot be said that private capital formation does not cause future public capital formation, it likely cannot be stated with definitiveness that private capital formation leads to public capital formation, either.

The specific model examined in table 3 contains the following form:

$$E(Priv_t \mid I_{t-1}) \neq E(Priv_t \mid J_{t-1})$$

Where the variable being examined, in this case the real public capital stock, Granger causes real private capital stock if the above relationship holds. In the model, I_{t-1}contains previous information on both the private capital stock and the public capital stock and J_{t-1}contains only information on past private capital stock.

The forthcoming tables in chapter five require an explanation for their contents. Each table reports the findings from six models testing for constant explained and explanatory variables with one exception. A country's real private capital stock in a given year is the dependent variable in every model with an error correction model rank assigned given the optimal rank for a full model with a certain lag of the real public capital stock, domestic credit as a share of GDP, population, size of real GDP, economic freedom, and financial openness. Each table shows the results of a Granger Causality test of a reduced form model

between the explanatory variable and the real private capital stock depending on the lag in years of public capital stock. For the fields under columns specifying a certain lag, a "+" sign indicates that the explanatory variable had a causal effect on the private capital stock, a "-" sign indicates that the explanatory variable did not have a causal effect on the private capital stock, and a blank entry meant that the full vector error correction model did not achieve full rank during the estimation process. The "Overall" column indicates the number of times a causal relationship was present over the up to six models for individual countries. Finally, the "Majority" column has a "+" sign in each field if the number of models showing a causal relationship for the specified variable was at least half of the models that achieved full rank status during the estimation process in individual countries.

Table 3. Results for Tests of Whether Changes in the Level of the Public Capital Stock Causes Changes in the Level of the Private Capital Stock by Public Capital Lag Type at 10% Level of Significance

Country	No Lag	1 Yr. Lag	2 Yr. Lag	3 Yr. Lag	4 Yr. Lag	5 Yr. Lag	Overall	Majority
Algeria			+	+	+	+	**4**	**+**
Bolivia			+	-	+	+	**3**	**+**
Cameroon			+	-			**1**	**+**
Cote d'Ivoire	+	+	-	+			**3**	**+**
DRC	+	+	-	-	-	-	**2**	**-**
Fiji			+	+	-	-	**2**	**+**
Ghana			+	-	-	-	**1**	**-**
Iran	-	-	-	+	-	-	**1**	**-**
Malawi	-	-	-	+	+	-	**2**	**-**
Malaysia			+	-	+	+	**3**	**+**
Mexico			-	-	+	+	**2**	**+**
Morocco	-	-	-	+	-	-	**1**	**-**
Nicaragua			+	+	+	+	**4**	**+**
Pakistan			+	+	+	+	**4**	**+**
Philippines	+	+	+	+	+	+	**6**	**+**
Sierra Leone			+	-	+	+	**3**	**+**
South Africa	-	-	-	+	+	+	**3**	**+**
Togo			+	+	+	+	**4**	**+**
Tunisia			+	-	+	+	**3**	**+**
Uganda	+	+	-	+	-	-	**3**	**+**
Uruguay			+	-	-	-	**1**	**-**
Zambia	-	+	-	+	-	-	**2**	**-**

Source: Author's Calculations
Note: For explanation of table, see pages 55 & 56

Results for Other Variables

In general, the full model with all explanatory variables effectively modeled the factors that drove private capital stock formation within developing countries. Of the seven variables controlled for in this study, all seven caused private capital formation in at least

one of the six primary models controlled for while four of the seven caused private capital formation in at least 50% of the models tested for which full rank status was attained. In particular, when all seven variables are controlled for, the combination of them drove private capital formation in 92 of the 101 models tested, and the null hypothesis of no causality could not be rejected in more than one year in any given country depending on the lag specification for public capital stock.

The specific model examined in table 4 contains the following form:

$$E(Priv_t \mid I_{t-1}) \neq E(Priv_t \mid J_{t-1})$$

Where the full model Granger causes real private capital stock if the above relationship holds. In the model, I_{t-1}contains previous information on both the private capital stock and the full model and J_{t-1}contains only information on past private capital stock.

Table 4. Results for Tests of Whether the Full Model Causes Changes in the Level of the Private Capital Stock by Public Capital Lag Type at 10% Level of Significance

Country	No Lag	1 Yr. Lag	2 Yr. Lag	3 Yr. Lag	4 Yr. Lag	5 Yr. Lag	Overall	Majority
Algeria			+	+	+	+	**4**	+
Bolivia			+	+	+	+	**4**	+
Cameroon			+	+			**2**	+
Cote	+	+	+	+			**4**	+
DRC	+	+	+	+	+	+	**6**	+
Fiji			+	+	+	+	**4**	+
Ghana			+	+	+	+	**4**	+
Iran	+	+	+	+	+	+	**6**	+
Malawi	-	-	+	+	+	+	**4**	+
Malaysia			+	+	+	+	**4**	+
Mexico			+	+	+	+	**4**	+
Morocco	-	-	+	+	+	+	**4**	+
Nicaragua			+	+	+	+	**4**	+
Pakistan			+	+	+	+	**4**	+
Philippines	+	+	+	+	+	+	**6**	+
Sierra Leone			+	+	+	+	**4**	+
South Africa	+	+	-	+	+	+	**5**	+
Togo			+	-	+	+	**3**	+
Tunisia			-	+	+	+	**3**	+
Uganda	+	+	+	+	+	+	**6**	+
Uruguay			+	+	+	+	**4**	+
Zambia	+	+	+	+	+	+	**6**	+

Source: Author's Calculations
Note: For explanation of table, see pages 55 & 56

As expected, changes in the level of population were consistently causal in affecting changes in the level of the population over the years and countries examined. Changes in the level of the population Granger caused changes in the level of the private capital stock in every country studied in at least one model specification, and it Granger caused changes in the level of the private capital stock in at least half of the models tested for which full rank status was attained in 91% of the countries examined. Interestingly, a larger share of countries indicated causality when public capital formation was lagged by at least two years (between 70% and 86% of the countries with viable models indicated causality when public capital was lagged at least two years) compared to just 43% and 56% of countries indicating a causal relationship between population and private capital stock when public capital was not lagged at all or lagged by just one year.

The specific model examined in table 5 contains the following form:

$$E(Priv_t \mid I_{t-1}) \neq E(Priv_t \mid J_{t-1})$$

Where population Granger causes real private capital stock if the above relationship holds. In the model, I_{t-1}contains previous information on both the private capital stock and the population and J_{t-1}contains only information on past private capital stock.

This result largely aligns with standard Solow Growth Model theories that investment growth in developing countries should be driven in part by labor force growth in order to ensure the capital-to-labor ratio does not deteriorate during the convergence process. While these tests do not provide insight on the elasticity of private capital stock growth to labor

growth, and the fact that population growth does differ from population growth further limits the definitiveness of these findings as a referendum on the validity of Solow Growth Models, they do provide weak evidence that there is some underlying truth to these models.

Table 5. Results for Tests of Whether Population Causes Changes in the Level of the Private Capital Stock by Public Capital Lag Type at 10% Level of Significance

Country	No Lag	1 Yr. Lag	2 Yr. Lag	3 Yr. Lag	4 Yr. Lag	5 Yr. Lag	Overall	Majority
Algeria			+	+	+	+	**4**	+
Bolivia			+	+	+	+	**4**	+
Cameroon			+	-			**1**	+
Cote d'Ivoire	+	+	+	-			**3**	+
DRC	-	-	-	+	-	-	**1**	-
Fiji			+	+	-	-	**2**	+
Ghana			+	+	+	-	**3**	+
Iran	-	-	+	-	+	+	**3**	+
Malawi	-	-	-	+	-	-	**1**	-
Malaysia			+	+	+	+	**4**	+
Mexico			+	+	+	+	**4**	+
Morocco	-	-	+	+	+	+	**4**	+
Nicaragua			+	+	+	+	**4**	+
Pakistan			+	+	+	+	**4**	+
Philippines	+	+	+	+	+	+	**6**	+
Sierra Leone			+	+	+	+	**4**	+
South Africa	+	+	+	+	+	+	**6**	+
Togo			+	+	+	-	**3**	+
Tunisia			+	+	+	+	**4**	+
Uganda	+	+	+	+	+	+	**6**	+
Uruguay			+	-	+	+	**3**	+
Zambia	+	+	-	+	-	-	**3**	+

Source: Author's Calculations
Note: For explanation of table, see pages 55 & 56

Institutions also appear to affect private capital formation in developing countries. The "Freedom" index was causal in at least one of the six public capital specification models in 91% of the countries which had functioning models. The only two countries where institutions did not Granger cause private capital formation were Fiji and Sierra Leone. Additionally, the Freedom index variable was causal at least half the time in individual countries in 77% of the countries examined in this study in which full rank status was attained.

The specific model examined in table 6 contains the following form:

$$E(Priv_t \mid I_{t-1}) \neq E(Priv_t \mid J_{t-1})$$

Where institutions Granger cause real private capital stock if the above relationship holds. In the model, I_{t-1}contains previous information on both the private capital stock and the institutions and J_{t-1}contains only information on past private capital stock.

Table 6. Results for Tests of Whether Institutions Cause Changes in the Level of Private Capital Stock by Public Capital Lag Type at 10% Level of Significance

Country	No Lag	1 Yr. Lag	2 Yr. Lag	3 Yr. Lag	4 Yr. Lag	5 Yr. Lag	Overall	Majority
Algeria			+	+	+	+	**4**	+
Bolivia			+	-	+	+	**3**	+
Cameroon			-	+			**1**	+
Cote d'Ivoire	+	-	+	-			**2**	+
DRC	+	+	+	+	+	+	**6**	+
Fiji			-	-	-	-	**0**	-
Ghana			-	+	-	-	**1**	-
Iran	+	-	+	+	+	+	**5**	+
Malawi	-	-	+	+	+	+	**4**	+
Malaysia			+	+	+	+	**4**	+
Mexico			+	+	+	+	**4**	+
Morocco	-	-	+	+	+	+	**4**	+
Nicaragua			+	-	+	+	**3**	+
Pakistan			-	+	-	-	**1**	-
Philippines	+	+	+	-	+	+	**5**	+
Sierra Leone			-	-	-	-	**0**	-
South Africa	+	+	-	+	-	-	**3**	+
Togo			+	-	+	+	**3**	+
Tunisia			-	+	-	-	**1**	-
Uganda	+	+	+	+	+	+	**6**	+
Uruguay			+	-	+	+	**3**	+
Zambia	+	+	+	+	-	-	**4**	+

Source: Author's Calculations
Note: For explanation of table, see pages 55 & 56

While not as definitive as the results for public capital stock, population, and freedom, the amount of credit provided by domestic institutions to the private sector as a share of a country's GDP ("Domestic Credit") also gave indications of being a causal driver of private capital formation. Domestic Credit was causal in at least one of the specifications in over two-thirds of the countries, and caused private capital formation in at least half of the models tested for which full rank status was attained in 50% of the countries where the

variable was causal in at least one model. Future studies on this subject could be improved by introducing a variable that is a function of both prevailing interest rates and the total amount of credit in the system as a share of GDP in order to account for the cost of financing in addition to the availability of financing for private companies.

The specific model examined in table 7 contains the following form:

$$E(Priv_t \mid I_{t-1}) \neq E(Priv_t \mid J_{t-1})$$

Where domestic credit as a share of GDP Granger causes real private capital stock if the above relationship holds. In the model, I_{t-1}contains previous information on both the private capital stock and domestic credit and J_{t-1}contains only information on past private capital stock.

Table 7. Results for Tests of Whether Domestic Credit as a Share of GDP Causes Changes in the Level of the Private Capital Stock by Public Capital Lag Type at 10% Level of Significance

Country	No Lag	1 Yr. Lag	2 Yr. Lag	3 Yr. Lag	4 Yr. Lag	5 Yr. Lag	Overall	Majority
Algeria			-	-	-	-	**0**	-
Bolivia			-	-	-	-	**0**	-
Cameroon			-	-			**0**	-
Cote d'Ivoire	+	+	-	-			**2**	+
DRC	-	-	+	-	-	-	**1**	-
Fiji			-	-	-	-	**0**	-
Ghana			-	+	-	-	**1**	-
Iran	-	-	+	+	+	+	**4**	+
Malawi	-	-	+	-	+	+	**3**	+
Malaysia			-	+	-	-	**1**	-
Mexico			+	+	-	-	**2**	+
Morocco	-	-	+	+	+	+	**4**	+
Nicaragua			-	-	-	-	**0**	-
Pakistan			-	-	-	-	**0**	-
Philippines	+	+	-	+	-	-	**3**	+
Sierra Leone			+	+	+	+	**4**	+
South Africa	+	+	+	+	+	+	**6**	+
Togo			+	-	-	+	**2**	+
Tunisia			-	+	-	-	**1**	-
Uganda	+	+	+	-	+	+	**5**	+
Uruguay			-	+	-	-	**1**	-
Zambia	+	+	+	-	+	+	**5**	+

Source: Author's Calculations
Note: For explanation of table, see pages 55 & 56

The results for the variable for financial openness ("Openness") weakly suggest that financial openness helps cause changes in the level of private capital formation, but the results are far from definitive. The variable was positive in at least one of six specifications in 78% of the countries examined. However, financial openness proved to be causal in at least half of the models tested for which full rank status was attained for 50% of the

countries. Furthermore, the variable was causal in just one of the model specifications in over half of the countries for which it was causal in one of the specifications. While the findings of this study do indicate some likelihood that changes in the level of financial openness causes changes in the level of private capital formation, the results must be classified as tentative at best.

The specific model examined in table 8 contains the following form:

$$E(Priv_t \mid I_{t-1}) \neq E(Priv_t \mid J_{t-1})$$

Where financial openness Granger causes real private capital stock if the above relationship holds. In the model, I_{t-1}contains previous information on both the private capital stock and financial openness and J_{t-1}contains only information on past private capital stock.

Table 8. Results for Tests of If Financial Openness Causes Changes in the Level of the Private Capital Stock by Public Capital Lag Type at 10% Level of Significance

Country	No Lag	1 Yr. Lag	2 Yr. Lag	3 Yr. Lag	4 Yr. Lag	5 Yr. Lag	Overall	Majority
Algeria			+	+	+	+	**4**	+
Bolivia			+	-	+	-	**2**	+
Cameroon			-	-			**0**	-
Cote d'Ivoire	+	+	-	+			**3**	+
DRC	+	+	-	-	+	-	**3**	+
Fiji			+	+	+	+	**4**	+
Ghana			+	-	-	-	**1**	-
Iran	+	-	-	-	-	-	**1**	-
Malawi	-	-	-	-	-	-	**0**	-
Malaysia			-	+	+	+	**3**	+
Mexico			+	-	+	+	**3**	+
Morocco	-	-	-	+	-	-	**1**	-
Nicaragua			+	-	+	-	**2**	+
Pakistan			-	-	-	-	**0**	-
Philippines	+	+	-	+	-	-	**3**	+
Sierra Leone			+	-	-	-	**1**	-
South Africa	+	+	-	-	-	-	**2**	-
Togo			-	-	-	-	**0**	-
Tunisia			-	+	-	-	**1**	-
Uganda	+	+	+	-	+	+	**5**	+
Uruguay			-	-	-	-	**0**	-
Zambia	+	+	-	+	-	-	**3**	+

Source: Author's Calculations
Note: For explanation of table, see pages 55 & 56

Perhaps most surprisingly, the variable that proved causal in changing the level of private capital formation in the fewest countries and the least amount of the time was the size of a country's economy in terms of gross domestic product ("GDP"). The level of GDP proved causal in just 73% of the countries examined in this study, and it was causal in at least half of the models tested for which full rank status was attained for just 41% of the countries where some evidence of causality existed. This could indicate that the size of the economy

alone does not affect changes in the level of the private capital stock and that changes in the size of the population is a more significant predictor of private capital stock level changes.

The specific model examined in table 9 contains the following form:

$$E(Priv_t \mid I_{t-1}) \neq E(Priv_t \mid J_{t-1})$$

Where GDP Granger causes real private capital stock if the above relationship holds. In the model, I_{t-1}contains previous information on both the private capital stock and GDP and J_{t-1}contains only information on past private capital stock.

Table 9. Results for Tests of If the Level of GDP Causes Changes in the Level of the Private Capital Stock by Public Capital Lag Type at 10% Level of Significance

Country	No Lag	1 Yr. Lag	2 Yr. Lag	3 Yr. Lag	4 Yr. Lag	5 Yr. Lag	Overall	Majority
Algeria			-	-	+	+	**2**	**+**
Bolivia			-	-	+	-	**1**	**-**
Cameroon			-	+			**1**	**+**
Cote d'Ivoire	+	+	-	-			**2**	**+**
DRC	+	+	-	-	+	+	**4**	**+**
Fiji			-	+	-	-	**1**	**-**
Ghana			+	+	+	+	**4**	**+**
Iran	+	-	+	-	+	+	**4**	**+**
Malawi	-	-	-	-	-	-	**0**	**-**
Malaysia			-	-	-	-	**0**	**-**
Mexico			-	-	-	-	**0**	**-**
Morocco	+	-	-	-	-	+	**2**	**-**
Nicaragua			-	+	-	-	**1**	**-**
Pakistan			+	+	-	-	**2**	**+**
Philippines	+	+	+	-	+	+	**5**	**+**
Sierra Leone			-	-	-	-	**0**	**-**
South Africa	+	+	-	-	-	-	**2**	**-**
Togo			-	-	-	-	**0**	**-**
Tunisia			-	-	-	-	**0**	**-**
Uganda	+	+	-	-	-	-	**2**	**-**
Uruguay			-	+	-	-	**1**	**-**
Zambia	+	+	+	-	+	+	**5**	**+**

Source: Author's Calculations
Note: For explanation of table, see pages 55 & 56

Reverse Causality Test Results

One of the more noteworthy findings from the study was that the stock of private capital formation was significantly more effective in driving changes in the explanatory variables than the opposite case. Nowhere was this more apparent than the variable for GDP. In particular, whereas changes in the level of the economy caused changes in the level of the

private capital stock in just 73% of the countries, changes in the level of the private capital stock caused changes in the level of GDP in every country studied, and it was causal in at least half of the models tested for which full rank status was attained for 82% of the countries. This was largely expected as the link between private investment and productivity is well documented. Thus, it should be no surprise that additional investment in productivity-enhancing technologies will lead to changes in the size of the economy.

The specific model examined in table 10 contains the following form:

$$E(GDP_t \mid I_{t-1}) \neq E(GDP_t \mid J_{t-1})$$

Where the private capital stock Granger causes GDP if the above relationship holds. In the model, I_{t-1}contains previous information on both the GDP and the private capital stock and J_{t-1}contains only information on past GDP.

Table 10. Results for Tests of Whether Changes in the Level of Private Capital Stock Cause Changes in the Level of GDP by Public Capital Lag Type at 10% Level of Significance

Country	No Lag	1 Yr. Lag	2 Yr. Lag	3 Yr. Lag	4 Yr. Lag	5 Yr. Lag	Overall	Majority
Algeria			+	+	+	-	3	+
Bolivia			+	-	-	+	2	+
Cameroon			+	+			2	+
Cote d'Ivoire	-	-	+	+			2	+
DRC	-	-	+	+	+	-	3	+
Fiji			+	+	+	+	4	+
Ghana			-	-	+	+	2	+
Iran	+	-	-	-	-	-	1	-
Malawi	-	-	-	+	-	-	1	-
Malaysia			+	-	+	+	3	+
Mexico			-	+	-	-	1	-
Morocco	-	-	+	+	+	-	3	+
Nicaragua			+	+	+	+	4	+
Pakistan			+	+	+	+	4	+
Philippines	-	+	+	+	+	-	4	+
Sierra Leone			+	+	+	+	4	+
South Africa	-	-	+	+	+	+	4	+
Togo			+	+	+	+	4	+
Tunisia			+	+	+	+	4	+
Uganda	-	-	+	-	+	+	3	+
Uruguay			-	+	-	-	1	-
Zambia	+	+	+	+	+	+	6	+

Source: Author's Calculations
Note: For explanation of table, see pages 55 & 56

Additionally, stronger evidence of reverse causality existed for Domestic Credit, Economic Freedom, and Financial Openness. Changes in the level of the private capital stock drove changes in the size of Domestic Credit in a country in 95% of the countries examined. These variables were causal in at least half of the models tested for which full rank status was attained for 82% of the countries where some evidence of causality existed. Changes

in the size of the Domestic Credit as a function of changes in the level of the private capital stock could reflect the phenomenon of better loan opportunities existing as a country's private sector becomes increasingly sophisticated. If a country's Domestic Credit-providing entities believe that they are likely to be repaid on a loan, they are more likely willing to extend the loan.

The specific model examined in table 11 contains the following form:

$$E(DomCred_t \mid I_{t-1}) \neq E(DomCred_t \mid J_{t-1})$$

Where the private capital stock Granger causes domestic credit as a share of GDP if the above relationship holds. In the model, I_{t-1}contains previous information on both the domestic credit as a share of GDP and the private capital stock and J_{t-1}contains only information on past size of the domestic credit as a share of GDP.

Table 11. Results for Tests of Whether Changes in the Level of Private Capital Stock Cause Changes in the Domestic Credit as a Share of GDP by Public Capital Lag Type at 10% Level of Significance

Country	No Lag	1 Yr. Lag	2 Yr. Lag	3 Yr. Lag	4 Yr. Lag	5 Yr. Lag	Overall	Majority
Algeria			+	+	+	+	4	+
Bolivia			+	-	+	+	3	+
Cameroon			-	-			0	-
Cote d'Ivoire	-	-	+	-			1	-
DRC	+	+	-	+	-	-	3	+
Fiji			-	+	-	-	1	-
Ghana			+	-	+	+	3	+
Iran	+	+	-	-	-	-	2	-
Malawi	+	+	-	+	-	-	3	+
Malaysia			+	+	+	+	4	+
Mexico			+	-	+	+	3	+
Morocco	+	+	-	+	-	+	4	+
Nicaragua			+	+	+	+	4	+
Pakistan			+	+	+	+	4	+
Philippines	-	-	+	+	+	+	4	+
Sierra Leone			+	+	+	+	4	+
South Africa	+	+	+	+	-	-	4	+
Togo			+	+	+	+	4	+
Tunisia			+	+	+	-	3	+
Uganda	+	+	+	+	+	+	6	+
Uruguay			+	+	+	+	4	+
Zambia	+	+	+	+	+	+	6	+

Source: Author's Calculations
Note: For explanation of table, see pages 55 & 56

Furthermore, changes in the stock of private capital caused changes in the Economic Freedom variable in 95% of the countries in at least one of the six specifications. It was also causal in at least half of the models tested for which full rank status was attained for over 68% of the countries where some evidence of causality existed. Finally, changes in the level of the private capital stock caused changes in a country's Openness rating in 86%

of the countries examined, and it was causal in at least half of the models tested for which full rank status was attained in over two-thirds of the countries where some evidence of causality existed. These results tentatively indicate that as firms in a country become increasingly affluent and sophisticated, they also become increasingly willing to push for governance and openness reforms that would result in increasingly profitable operations on the part of the firm.

The specific model examined in table 12 contains the following form:

$$E(Inst_t | I_{t-1}) \neq E(Inst_t | J_{t-1})$$

Where the private capital stock Granger causes the ratings of institutions if the above relationship holds. In the model, I_{t-1}contains previous information on both the quality of institutions and the private capital stock and J_{t-1}contains only information on past quality of institutions.

Table 12. Results for Tests of Whether Changes in the Level of Private Capital Stock Cause Changes in the rating for Economic Freedom by Public Capital Lag Type at 10% Level of Significance

Country	No Lag	1 Yr. Lag	2 Yr. Lag	3 Yr. Lag	4 Yr. Lag	5 Yr. Lag	Overall	Majority
Algeria			+	+	+	-	3	+
Bolivia			+	-	-	+	2	+
Cameroon			-	+			1	+
Cote d'Ivoire	+	+	+	+			4	+
DRC	+	+	+	+	+	+	6	+
Fiji			+	-	+	+	3	+
Ghana			-	-	-	-	0	-
Iran	+	+	-	-	-	-	2	-
Malawi	+	+	-	-	-	-	2	-
Malaysia			-	+	-	-	1	-
Mexico			+	+	+	+	4	+
Morocco	+	+	+	+	+	+	6	+
Nicaragua			+	+	+	+	4	+
Pakistan			+	+	+	+	4	+
Philippines	+	+	+	+	+	-	5	+
Sierra Leone			+	-	+	+	3	+
South Africa	-	-	+	-	-	-	1	-
Togo			-	-	-	+	1	-
Tunisia			-	+	-	-	1	-
Uganda	+	+	+	+	+	+	6	+
Uruguay			+	+	+	+	4	+
Zambia	+	+	+	+	+	+	6	+

Source: Author's Calculations
Note: For explanation of table, see pages 55 & 56

The specific model examined in table 13 contains the following form:

$$E(Open_t \mid I_{t-1}) \neq E(Open_t \mid J_{t-1})$$

Where the private capital stock Granger causes financial openness if the above relationship holds. In the model, I_{t-1}contains previous information on both the financial openness of a

country and the private capital stock and J_{t-1}contains only information on past financial openness.

Table 13. Results for Tests of Whether Changes in the Level of Private Capital Stock Cause Changes in the rating for Financial Openness by Public Capital Lag Type at 10% Level of Significance

Country	No Lag	1 Yr. Lag	2 Yr. Lag	3 Yr. Lag	4 Yr. Lag	5 Yr. Lag	Overall	Majority
Algeria			+	+	+	-	3	+
Bolivia			+	-	-	+	2	+
Cameroon			-	+			1	+
Cote d'Ivoire	-	-	+	+			2	+
DRC	-	-	+	+	+	-	3	+
Fiji			+	-	+	+	3	+
Ghana			-	-	-	-	0	-
Iran	+	-	-	-	-	-	1	-
Malawi	-	-	-	+	-	-	1	-
Malaysia			+	-	+	+	3	+
Mexico			-	-	-	-	0	-
Morocco	-	-	-	+	-	-	1	-
Nicaragua			+	+	+	+	4	+
Pakistan			+	+	+	+	4	+
Philippines	-	-	+	-	+	+	3	+
Sierra Leone			-	-	-	-	0	-
South Africa	-	-	-	+	-	-	1	-
Togo			+	+	+	+	4	+
Tunisia			+	+	+	+	4	+
Uganda	+	+	+	+	+	+	6	+
Uruguay			+	+	+	+	4	+
Zambia	-	-	+	+	+	+	4	+

Source: Author's Calculations
Note: For explanation of table, see pages 55 & 56

Changes in the level of the private capital stock drove changes in the size of the population in 91% of the countries examined in this study, and it was causal in at least half of the models tested for which full rank status was attained for 73% of the countries where some evidence of causality existed. Although fertility rates generally decline as a country's citizenry becomes wealthier, it is possible that these findings reflect the fact that as a country's private capital stock grows larger, it can devote additional resources to healthcare which results in a reduction in the death rate that exceeds any declines the birth and/or fertility rate for the periods examined.

The specific model examined in table 14 contains the following form:

$$E(Pop_t \mid I_{t-1}) \neq E(Pop_t \mid J_{t-1})$$

Where the private capital stock Granger causes population if the above relationship holds. In the model, I_{t-1}contains previous information on both the population and the private capital stock and J_{t-1}contains only information on past population.

Table 14. Results for Tests of Whether Changes in the Level of Private Capital Stock Cause Changes in the Level of the Population by Public Capital Lag Type at 10% Level of Significance

Country	No Lag	1 Yr. Lag	2 Yr. Lag	3 Yr. Lag	4 Yr. Lag	5 Yr. Lag	Overall	Majority
Algeria			+	+	+	+	4	+
Bolivia			+	-	+	+	3	+
Cameroon			-	+			1	+
Cote d'Ivoire	+	+	+	+			4	+
DRC	-	-	+	+	-	-	2	-
Fiji			+	-	+	+	3	+
Ghana			-	-	+	-	1	-
Iran	+	+	-	-	-	-	2	-
Malawi	-	-	-	+	-	-	1	-
Malaysia			+	-	+	+	3	+
Mexico			-	-	-	-	0	-
Morocco	+	+	-	+	-	-	3	+
Nicaragua			+	+	+	+	4	+
Pakistan			+	+	+	+	4	+
Philippines	+	+	+	-	+	+	5	+
Sierra Leone			-	-	-	-	0	-
South Africa	+	+	-	+	-	-	3	+
Togo			+	+	+	+	4	+
Tunisia			+	+	+	+	4	+
Uganda	-	-	+	+	+	+	4	+
Uruguay			+	+	+	+	4	+
Zambia	-	-	+	+	+	+	4	+

Source: Author's Calculations
Note: For explanation of table, see pages 55 & 56

Given that all of these variables meet one of the necessary criteria for being a good candidate for having a statistically significant effect at predicting changes in the level of private capital formation, they will be included in the final model that attempts to determine whether public capital formation crowds-in or crowds-out private capital formation after other explanatory variables are controlled for in the model.

CHAPTER 6: CROWDING-IN VS CROWDING-OUT ANALYSIS

The final important test when it comes to analyzing the relationship between the levels of public and private capital stock is to answer the question of whether growth in the level of the public capital stock cause an increase ("crowding in") or decrease ("crowding out") in the growth of the private capital stock. The results of this study indicate that increases in the level of the public capital stock have a crowding-in effect on the level of the private capital stock anywhere between five-ninths and three-fourths of the time depending on the metric analyzed. For the fifty-seven cases where a causal relationship between a simultaneous or lagged value of public capital stock and private capital stock exist, forty of them indicate a crowding-in relationship. When broken down in country terms, thirteen of the twenty-two countries consistently display a crowding-in relationship after the other variables are controlled for in the VECM regressions, five consistently indicate a crowding-out relationship, and five show both types of relationships.

However, of particular interest is the fact that the relationships become much more consistent when the value of public capital stock is lagged by two years or more. In the forty-eight such instances where a causal relationship exists, thirty-six models display a crowding-in relationship. In country terms, 66% of the countries consistently display a crowding-in relationship, 29% consistently display a crowding-out relationship, and Algeria displays both at various lags. These findings bolster the hypothesis that there is a lagged relationship between public capital formation and a crowding-in effect on private

capital formation while a crowding-out relationship is more likely to exist when public capital formation and private capital formation occur closer together. Furthermore, with the exception of Togo, every country that was able to generate a vector error correction model with full rank for at least three different lags with a causal relationship indicated that a crowding-in effect between public capital and private capital was present.

While there is a large range of values of the elasticity of private capital stock growth with respect to public capital formation, some trends are quite apparent when the mean and median elasticity values for public capital formation's effect on private capital formation across the breadth of the sample of twenty-two countries. The mean value of the elasticity of private capital stock growth with respect to public capital formation went from negative values when contemporaneous values (-0.22) and one year lag (-0.13) of public capital stock was included to positive values during the two year lag (0.10), three year lag (0.08), four year lag (0.13), and especially the five year lag (0.36). When median elasticity values are considered, the positive effect of public capital stock growth on private capital stock growth begins being evident when public capital stock is only lagged by one year, with the positive effect accelerating when public capital is lagged by four and, especially, five years. The results of these models are shown in table 15.

The vector error correction models for each individual country takes the following functional forms in aggregate:

$$\Delta Priv_t = \prod Priv_{t-1} + \Phi_l^* \Delta Priv_{t-1} + \varepsilon_t$$

Δ is the differencing operator, such that $\Delta Priv_t = Priv_t - Priv_{t-1}$; $\Pi = \alpha\beta'$

α and β are $k \times r$ matrices and Φ_I^* is a $k \times k$ matrix.

It has an equivalent VAR(p) representation:

$$Priv_t = \delta + (I_k + \Pi + \Phi_I^*)Priv_{t-1} + \sum_{i=2}^{p-1}(\Phi_i^* - \Phi_{i-1}^*)\, Priv_{i-1} - \Phi_{p-1}^* Priv_{t-p} + \varepsilon_t$$

I_k is a $k \times k$ identity matrix in this VAR(p) representation

The tables on the following pages are based on the following equations based on VECM(1) estimates:

$$\Delta Priv_t = Priv_{t-1} + Lag(x)Pub_{t-1} + Pop_{t-1} + GDP_{t-1} + DomCred_{t-1} + Open_{t-1} + Inst_{t-1} + \varepsilon_t$$

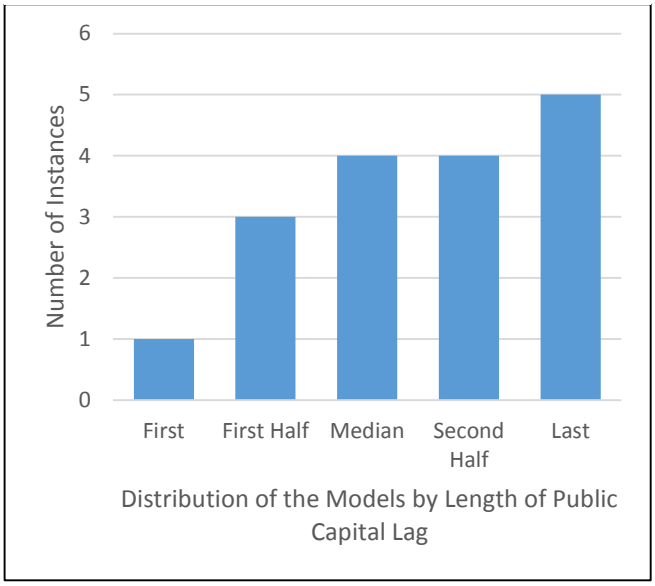
The lags for "x" in the public capital stock variable ranged between 0 and 5 based on how many years of lags of public capital stock were implemented in a given equation.

Table 15: Elasticity of Private Capital Stock Growth with Respect to Public Capital Formation by Public Capital Stock Lag

Country	No Lag	1 Year Lag	2 Year Lag	3 Year Lag	4 Year Lag	5 Year Lag
Algeria			(0.45)	(0.17)		0.81
Bolivia			0.04		0.32	0.49
Cameroon			0.07			
Cote d'Ivoire	(0.04)	0.12		(0.04)		
DRC	0.13	0.07				
Fiji			0.15	0.17		
Ghana			0.02			
Iran				(0.03)		
Malawi				(0.26)	(0.32)	
Malaysia			0.12		0.33	0.40
Mexico					0.33	0.24
Morocco				(0.22)		
Nicaragua			1.33	1.00	0.31	1.35
Pakistan			0.03	0.06	0.10	0.14
Philippines	(0.51)	(0.92)	0.17	0.06	0.13	0.15
Sierra Leone			0.29		0.02	0.33
South Africa				0.18	0.19	0.01
Togo			(0.15)	(0.14)	(0.10)	(0.04)
Tunisia			0.09		0.10	0.09
Uganda	(0.44)	(0.09)		0.14		
Uruguay			(0.37)			
Zambia		0.16		0.26		
Average	**(0.22)**	**(0.13)**	**0.10**	**0.08**	**0.13**	**0.36**
Median	**(0.24)**	**0.07**	**0.07**	**0.06**	**0.13**	**0.24**
Positive	**1**	**3**	**10**	**7**	**9**	**10**
Minus	**3**	**2**	**3**	**6**	**2**	**1**
Positive Share	**25%**	**60%**	**77%**	**54%**	**82%**	**91%**
Maximum Value	**0.13**	**0.16**	**1.33**	**1.00**	**0.33**	**1.35**
Minimum Value	**(0.51)**	**(0.92)**	**(0.45)**	**(0.26)**	**(0.32)**	**(0.04)**

Source: Author's Calculations

Figure 16: Optimal Estimation Models of Countries Based on Public Capital Lag Length



Source: Author's Calculations

Although the intent of this study was to identify if there are trends in public capital's effect on private capital stock when public capital is lagged, and not to identify the optimal model for each individual country, an investigation of the Schwarz-Bayesian Criterion (SBC) scores for each country's optimal model is still a useful exercise because of the lack of definitiveness of the findings. With the exception of if the lowest SBC score was in the first model that achieved full rank, the lowest SBC score was roughly evenly distributed across models with smaller lags of public capital to models with the largest lags of public capital. That said, there was some indication that models were optimal more often when longer lags of public capital were utilized. This bolsters the view that measuring public capital's impact on private capital formation is best done with lagged values. If only the optimal models according to SBC scores are considered, fifteen of the twenty-two countries indicate a crowding-in relationship between public capital formation and private capital formation. The results of these tests are found in table 16.

Table 16: Schwarz-Bayesian Criterion Scores of Full Models Based on Public Capital Lag

Country	No Lag	1 Year Lag	2 Year Lag	3 Year Lag	4 Year Lag	5 Year Lag	Optimal Lag
Algeria			-28.79	-28.01		-30.01	**5**
Bolivia			-46.89		-47.57	-47.73	**4**
Cameroon			-41.53				**2**
Cote d'Ivoire	-37.28	-33.53		-31.95			**0**
DRC	-37.89	-33.56					**0**
Fiji			-49.73	-49.53			**2**
Ghana			-40.77				**2**
Iran				-13.20			**3**
Malawi				-40.95	-40.35		**3**
Malaysia			-19.66		-21.80	-22.27	**5**
Mexico					-4.12	-3.56	**4**
Morocco				-19.49			**3**
Nicaragua			-45.52	-45.58	-46.46	-45.36	**4**
Pakistan			-23.95	-24.00	-23.88	-23.92	**3**
Philippines	-23.15	-19.03	-22.44	-22.09	-21.68	-22.60	**0**
Sierra Leone			-51.16		-51.80	-52.16	**5**
South Africa				-10.31	-10.90	-11.31	**5**
Togo			-51.48	-52.01	-52.22	-53.18	**5**
Tunisia			-30.51		-30.15	-30.36	**5**
Uganda	-46.62	-42.20		-47.05			**3**
Uruguay			-41.83				**2**
Zambia		-41.26		-40.39			**1**

Source: Author's Calculations

Given that a causal relationship exists from private investment to public investment in just around one-third of instances, an attempt to determine whether a crowding-in or a crowding-out relationship would be misplaced at this time.

CHAPTER 7: ANALYSIS AND CONCLUSION

The findings of this research, while preliminary, help shed light on the debate of whether public infrastructure investment increases future levels of the private capital stock. This is especially important given the focus on how countries can break out of the so-called "middle income trap"—where a country reaches a certain level of affluence, but fails to reach a level of real per capita income that is commensurate with those present in advanced economies. Although the results are not unanimous in indicating that increases in the level of the public capital stock lead to increases in the level of the private capital stock, the fact that two-thirds of developing economies and three-quarters of total models in this study display a crowding-in relationship when public capital formation is lagged by at least two years provides important evidence indicating as much. This study is unique from others in the fact that nearly two dozen countries are analyzed. While future researchers should be able to control for additional factors in order to identify what causes public spending to crowd-in or crowd-out private investment in certain countries, the breadth of this panel and the decided majority of countries indicating a crowding-in relationship provide an important starting point for future researchers.

The most important finding from the first portion of this study was the tightly-linked relationship between public infrastructure capital stock and investment and private capital stock and investment. Electrical capacity, paved road networks, rail networks, and telecommunications networks all grew faster during the 2000s-plus compared to the 1990s-plus in both high income and middle income countries. Port traffic and new water and

sanitation connections grew more slowly, but still robustly, in both middle income and high income countries during the 2000s-plus compared to the 1990s-plus. This strong growth in new public infrastructure capital stock during the 2000s-plus coincided with a decisive increase in the privately-held capital stock in most developing economies. An examination of the trend growth in the private capital stock and public infrastructure capital stock of developing economies indicated that the growth in the public infrastructure capital stock generally preceded the growth in the private capital stock by two to three years. The leading effect was more pronounced as countries became wealthier.

The results of this research largely aligned with previous research in finding some tentative evidence for a crowing-in effect between values of the level of the public capital stock and future levels of private investment. Unfortunately, the small number of instances in which a causal relationship exists between lagged values of private and investment and public investment make any attempt at forming a preliminary—let alone a definitive—conclusion regarding a crowding-in or crowding-out relationship from private capital to public capital unwise. Consequently, the policy implications for this result are not definitive. If a crowding-in relationship exists between past values of the level of the private capital stock and future values of public capital stock, then it implies that governments should devote additional resources to jointly planning public works projects in order to make the relationship between public and private capital as complementary as possible as a country develops. If no relationship exists or growth in the level of the private capital stock eventually crowds out future levels of pubic capital stock, however, the policy implications are vastly different for public institutions. In this case, governments should devote the vast

majority of their resources to implementing what they deem to be the optimal public works investments and let the private sector respond accordingly to the various improvements in traditional and social public infrastructure. Additionally, any policy can be enhanced by improving the quality of public institutions in order to make sure that any public investment is made with the best interests of a country's citizens—both current and future—in mind. Needless to say, further research needs to be conducted as this question is of the utmost importance for the development process.

The findings concerning population and institutions are not surprising. The quality institutions have long been regarded as important in affecting the development process, and this study merely confirms that this relationship persists. The definitiveness of the finding is quite welcome. The tentativeness of the findings for Domestic Credit to the private sector and financial openness in affecting changes in the stock of private capital indicate that internal improvements may be more important in the development process than opening up domestic firms to foreign competition. Although some of the leading firms may agitate to open economies up as soon as possible, the findings of this study indicate that government institutions should focus their efforts on reforming themselves based on best international practices so that they can create an environment friendly to businesses before they subject their countries' firms to international competition.

The conclusions of this study are tentative, but—even in their preliminary stage—the insights and findings from this study shed much-needed light on some of the key questions

researchers have raised when looking at what helps countries go from developing status to advanced status. Future studies into this subject will benefit tremendously from having access to larger samples for multivariate studies where additional confidence can be placed in the findings. In certain model specifications, there were as few as fifteen observations while the maximum number in any given country was thirty-two observations. While tentative conclusions can be drawn from this study, additional observations will prove particularly helpful in ensuring future conclusions can be made with a higher degree of confidence. Longer time series will also allow for more tailored ARMA model selection as models were limited to a maximum selection of AR(1) models given the short time-series utilized in this report. Furthermore, certain variables that were hypothesized as potentially causal, such as real interest rates and exchange rate volatility, had to be discarded during the model creation process because of an inability to achieve full rank during the estimation process. In future decades many of these concerns will be irrelevant, but they will continue to plague time-series studies of the development process in developing economies for some time. Future research should also explore different combinations of variables for individual countries as opposed to broader ranging attempts to make conclusions about the development process writ large in emerging economies.

Nonetheless, the findings of this study largely support the a priori hypothesis that, even with some lag, increases in the stock of public capital facilitate the growth in the stock in private capital in developing economies. This study provisionally finds that there is a lag time between when public investment occurs and when the accelerator effect manifests itself with private investment, although the exact lag time appears to vary by country.

Further research needs to occur surrounding whether private investment helps drive public investment as well with a lag effect, as the finding from this investigation are largely inconclusive. Building better infrastructure, such as paved roads and power stations, is not sufficient by itself to help drive private investment growth to levels where citizens approach a level of affluence that advanced economy citizens enjoy. It is imperative on the part of governments to create a regulatory environment for the private sector that supports their goals and provides a level playing field for all participants in the market economy. A deeper pool of credit for the private sector and an open economy also appear to offset the investment process, although the solidity of these insights is below those for public investment and strong institutions. In many ways this report should be considered the first step in the process of determining what drives private investment in developing economies using time-series analysis that is more suited to the questions being asked. It is certainly not the last. However, the findings of this study do support the idea that governments in developing economies should focus their efforts on reforming their institutions and providing high quality infrastructure if they want a successful and thriving private sector that is willing to invest in hopes of a more prosperous tomorrow.

Bibliography

Aschauer, David Alan. “Is Public Expenditure Productive?” *Journal of Monetary Economics*, 1989, 177–200.

Atukeren, Erdal. “Interactions between Public and Private Investment: Evidence from Developing Economies.” *Kykols* 58, no. 3 (July 2005): 307–30.

Bairam, Erkin, and Bert Ward. “The Externality Effect of Government Expenditure on Investment in OECD Countries.” *Applied Economics* 25, no. 6 (1993): 711–16. doi:10.1080/00036849300000123.

Barro, Robert. “Government Spending in a Simple Model of Endogenous Growth.” *Journal of Political Economy* 98, no. 5 (October 1990): S103–S125.

Barro, Robert J. *Output Effects of Government Purchases*. Working Paper. National Bureau of Economic Research, 1980. http://www.nber.org/papers/w0432.

Bischoff, Charles. “Business Investment in the 1970s: A Comparison of Models.” *Brookings Paper on Economic Activity*, no. 1 (1971): 13–63.

Blejer, Mario, and Mohsin Khan. “Government Policy and Private Investment in Developing Countries.” *Staff Papers-International Monetary Fund* 31, no. 2 (June 1984): 379–403.

Calderón, César, Enrique Moral-Benito, and Luis Servén. *Is Infrastructure Capital Productive? A Dynamic Heterogeneous Approach*. Banco de Espana Working Paper. Banco de Espana, 2011. http://ideas.repec.org/p/bde/wpaper/1103.html.

Canning, David, Peter Pedroni, George Vonfurstenberg, Eric Leeper, Gary Madden, Salvador Ortigueira, and Lucie Schmidt For Their. *The Effect of Infrastructure on Long Run Economic Growth*, n.d.

Cavallo, Eduardo, and Christian Daude. “Public Investment in Developing Economies: A Blessing or Curse?” *Inter-American Development Bank Research Department* Working Paper #648 (October 2008): 1–42.

Chontanawat, Jaruwan, Lester Charles Hunt, and Richard G. Pierse. *Causality between Energy Consumption and GDP: Evidence from 30 OECD and 78 Non-OECD Countries*. Surrey Energy Economics Centre (SEEC), School of Economics Discussion Papers (SEEDS). Surrey Energy Economics Centre (SEEC), School of Economics, University of Surrey, June 2006. http://econpapers.repec.org/paper/surseedps/113.htm.

Christodoulakis, Nicos, and Sarantis Kalyvitis. *Structural Funds: Growth, Employment and the Environment: Growth, Employment, and the Environment : Modelling and Forecasting the Greek Economy*. Springer Science & Business Media, 2001.

Demetriades, Panicos O., and Theofanis P. Mamuneas. “Intertemporal Output and Employment Effects of Public Infrastructure Capital: Evidence from 12 OECD Economics.” *Economic Journal* 110, no. 465 (2000): 687–712.

Eberts, Randall W. *Estimating the Contribution of Urban Public Infrastructure to Regional Growth*. Working Paper. Federal Reserve Bank of Cleveland, 1986. http://ideas.repec.org/p/fip/fedcwp/8610.html.

Erden, Lutfi, and Randall Holcombe. “The Effects of Public Investment on Private Investment in Developing Economies.” *Public Finance Review* 33, no. 5 (September 2005): 575–602. doi:10.1177/1091142705277627.

———. “The Linkage between Public and Private Investment: A Co-Integration

Analysis of a Panel of Developing Economies." *Eastern Economic Journal* 32, no. 3 (Summer 2006): 479–92.
Erenburg, S. J. "The Real Effects of Public Investment on Private Investment." *Applied Economics* 25, no. 6 (1993): 831–37. doi:10.1080/00036849300000137.
Erenburg, S. J., and Mark E. Wohar. "Public and Private Investment: Are There Causal Linkages?" *Journal of Macroeconomics* 17, no. 1 (1995): 1–30.
Esfahani, Hadi Salehi, and Maria Teresa Ramirez. "Institutions, Infrastructure, and Economic Growth." *Journal of Development Economics* 70, no. 2 (2003): 443–77.
Everhart, Stephen, and Mariusz Sumlinski. *Trends in Private Investment in Developing Countries*. 44th ed. International Finance Corporation, Discussion Paper. The World Bank, 2001. http://elibrary.worldbank.org/doi/book/10.1596/0-8213-5010-2.
Greene, Joshua, and Delano Villaneva. "Private Investment in Developing Economies: An Empirical Analysis." *Staff Papers-International Monetary Fund* 38, no. 1 (March 1991): 33–58.
Hatano, Toshiya. "Crowding-In Effect of Public Investment on Private Investment." *Policy Research Institute, Ministry of Finance, Japan, Public Policy Review* 6, no. 1 (February 2010): 105–20.
"Infrastructure Productivity: How to Save $1 Trillion a Year | McKinsey & Company." Accessed September 1, 2014. http://www.mckinsey.com/insights/engineering_construction/infrastructure_productivity.
Investing in Infrastructure: What Is Needed from 2000 to 2010? Policy Research Working Papers. The World Bank, 2003. http://elibrary.worldbank.org/doi/book/10.1596/1813-9450-3102.
Is Infrastructure Capital Productive? A Dynamic Heterogeneous Approach. Policy Research Working Papers. The World Bank, 2011. http://elibrary.worldbank.org/doi/book/10.1596/1813-9450-5682.
José Emilio Boscá, Francisco Javier Escribá. "The Effect of Public Infrastructure on the Private Productive Sector of Spanish Regions." *Journal of Regional Science* 42, no. 2 (2002): 301–26. doi:10.1111/1467-9787.00260.
Jorgenson, Dale. "Econometric Studies of Investment Behavior: A Survey." *Journal of Economic Literature* 9, no. 4 (December 1971): 1111–47.
Kamps, Christophe. *The Dynamic Macroeconomic Effects of Public Capital: Theory and Evidence for OECD Countries*. Springer Science & Business Media, n.d.
Lora, Eduardo. "Public Investment in Infrastructure in Latin America: Is Debt the Culprit?" *Research Development Working Paper 498*, January 2007, 1–23.
Mittnik, Stefan, and Thorsten Neumann. "Dynamic Effects of Public Investment: Vector Autoregressive Evidence from Six Industrialized Countries." *Empirical Economics* 26, no. 2 (May 1, 2001): 429–46. doi:10.1007/s001810000064.
Monadjemi, Mehdi S. "Fiscal Policy and Private Investment Expenditure: A Study of Australia and the United States." *Applied Economics* 25, no. 2 (1993): 143–48. doi:10.1080/00036849300000018.
OECD. *Infrastructure to 2030*. Paris: Organisation for Economic Co-operation and Development, 2006. http://www.oecd-ilibrary.org/content/book/9789264023994-

en.
Oshikoya, Temitope. “Macroeconomic Determinants of Domestic Private Investment in Africa: An Empirical Analysis.” *Economic Development and Cultural Change* 42, no. 3 (April 1994): 573–96.
Otto, Glenn D., and Graham M. Voss. “Public Capital and Private Production in Australia.” *Southern Economic Journal* 62, no. 3 (January 1996): 723. doi:10.2307/1060890.
Pereira, Alfredo M. “On the Effects of Public Investment on Private Investment: What Crowds in What?” *Public Finance Review* 29, no. 1 (January 1, 2001): 3–25. doi:10.1177/109114210102900101.
Pradhan, B.K., D.K. Ratha, and Atul Sarma. “Complementarity between Public and Private Investment in India.” *Journal of Development Economics* 33, no. 1 (July 1990): 101–16.
Ramirez, Miguel. “Public and Private Investment in Mexico, 1950-90: An Empirical Analysis.” *Southern Economic Journal* 61, no. 1 (July 1994): 1.
Rioja, Felix K. “Filling Potholes: Macroeconomic Effects of Maintenance versus New Investments in Public Infrastructure.” *Journal of Public Economics* 87, no. 9–10 (2003): 2281–2304.
Romp, Ward, and Jakob de Haan. *Public Capital and Economic Growth: A Critical Survey*. EIB Paper. European Investment Bank, Economics Department, 2005. http://ideas.repec.org/p/ris/eibpap/2005_002.html.
Sanchez-Robles, Blanca. *Infrastructure Investment and Growth: Some Empirical Evidence*. SSRN Scholarly Paper. Rochester, NY: Social Science Research Network, January 1, 1998. http://papers.ssrn.com/abstract=2131639.
Shioji, Etsuro. “Public Capital and Economic Growth: A Convergence Approach.” *Journal of Economic Growth* 6, no. 3 (September 1, 2001): 205–27. doi:10.1023/A:1011395732433.
Smith, Ron P. “Estimation and Inference with Non-Stationary Panel Time-Series Data,” 2001.
Voss, Graham M. “Public and Private Investment in the United States and Canada.” *Economic Modelling* 19, no. 4 (2002): 641–64.
“WHO | Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level.” *WHO*. Accessed August 24, 2014. http://www.who.int/water_sanitation_health/wsh0404/en/.

Appendices

Appendix A: Process for Deriving US Dollar Amounts for Value of Infrastructure Assets Globally

1. Estimate US dollar value in 2000 of infrastructure asset: Multiply 2000 unit value by 2000 USD price per unit
2. Estimate infrastructure asset share of US GDP in 2000: Divide infrastructure asset USD value in 2000 by current USD GDP in 2000
3. Estimate LCU dollar value in 2000 of infrastructure unit: Multiply infrastructure asset share of GDP in 2000 by current LCU GDP in 2000
4. Estimate 2000 LCU price per unit of infrastructure asset in 2000: Divide LCU dollar value in 2000 of infrastructure unit by 2000 infrastructure asset component amount
5. Estimate LCU price per unit of infrastructure asset for 1990-2010: Multiply 2000 LCU price per unit of infrastructure asset by (GDP Deflator value of Desired Year/GDP Deflator Value of 2000)
6. Estimate LCU Share of GDP of infrastructure assets in a country for 1990-2010: Multiply desired 1990-2010 LCU price per unit of infrastructure asset by total units of infrastructure asset in desired 1990-2010 and divide by desired 1990-2010 GDP
7. Estimate USD Value of Infrastructure asset in a country for 1990-2010: Multiply LCU share of GDP of infrastructure asset in a country for desired 1990-2010 year by desired 1990-2010 US GDP
8. Estimate the USD price per unit of infrastructure Asset for 1990-2010-Divide USD Value of Infrastructure asset in a country for desired 1990-2010 year by total infrastructure component amount in country for desired 1990-2010 year

9. Create Real Price Index for change in a country's real USD value of infrastructure asset: Divide desired USD price per unit of infrastructure asset in desired 1990-2010 year by 2000 USD price per unit

Appendix B: Process for Creating Estimates of Asset Values

- All asset values expressed in current US$ terms
- Pricing adjusted for real terms relative to base years as a function of GDP deflator changes in local currency terms
- Pricing further adjusted based on changes in the exchange rate in a given year between local currency and US dollar

Appendix C: Pricing Determination

- Paved Roads
    - Function of Real USD GDP per capita as of 2005 (Base Year=2000)
        - For GDPpc<$5,000=$200,000
        - For $5,000<GDPpc<$10,000=$200,000 +(((GDPpc-5,000)/1000)*$40,000)
        - For GDPpc>$10,000=400,000
    - Per kilometer terms
    - Source: OECD-Infrastructure to 2030, p. 225
- Railways
    - Advanced economies, ex. Japan-$900,000 per kilometer, including associated rolling stock (Base Year=2000)
        - Source: World Bank, Investing in Infrastructure, p. 12

    - Japan-$3,300,000 per kilometer, including associated rolling stock (Base Year=2000)
        - Source: OECD-Infrastructure to 2030, p. 228
    - Middle and Lower Income economies-$250,000 per kilometer, including associated rolling stock (Base Year=2000)
        - Source: OECD-Infrastructure to 2030, p. 228
- Electricity
    - $1,900 per kilowatt of generating capacity, including associated network cost (Base Year=2000)
    - Source: World Bank, Investing in Infrastructure, p. 12
- Port
    - $348 per TEU (Base Year=2000)
    - Source: Infrastructure and Employment Creation in the Middle East and North Africa, p. 14
- Sanitation
    - Advanced Economies: $1,150 per head of household (Base Year=2000)
    - Developing Economies: $800 per connected household (Base Year=2000)
    - Source: OECD-Infrastructure to 2030, p. 253
- Water
    - $750 per head of household (Base Year=2000)
    - Source: OECD-Infrastructure to 2030, p. 253
- Fixed Telephone Lines
    - OECD

        - Pre-2005: $1,500 per line (Base Year=2005)
        - 2005-2010: $1,500 per line for 2004 lines plus $1,000 per post-2004 line, $950 post 2010 line
        - Source: OECD-Infrastructure to 2030, p. 109
    - Non- OECD
        - Pre-2005: $700 per line (Base Year=2005)
        - 2005-2010: $700 per line for 2004 lines plus $400 per post-2004 line, $350 post 2010 line
        - Source: OECD-Infrastructure to 2030, p. 109
        -

- Mobile Phone Lines
    - OECD
        - Pre-2005: $1,000 per subscription (Base Year=2005)
        - 2005-2010: $1,000 per subscription for 2004 subscription plus $700 per post-2004 subscription
        - Source: OECD-Infrastructure to 2030, p. 109
    - Non-OECD
        - Pre-2005: $700 per subscription (Base Year=2005)
        - 2005-2010: $700 per subscription for 2004 lines plus $300 per post-2004 subscription
        - Sources: World Bank, Investing in Infrastructure, p. 12; OECD-Infrastructure to 2030, p. 109
- Broadband Connections

- OECD
    - Pre-2005: $1,500 per line (Base Year=2005)
    - 2005-2010: $1,500 per line for 2004 lines plus $1,000 per post-2004 line, $950 post 2010 line
    - Source: OECD-Infrastructure to 2030, p. 109
- Non- OECD
    - Pre-2005: $700 per line (Base Year=2005)
    - 2005-2010: $700 per line for 2004 lines plus $400 per post-2004 line, $350 post 2010 line
    - Source: OECD-Infrastructure to 2030, p. 109